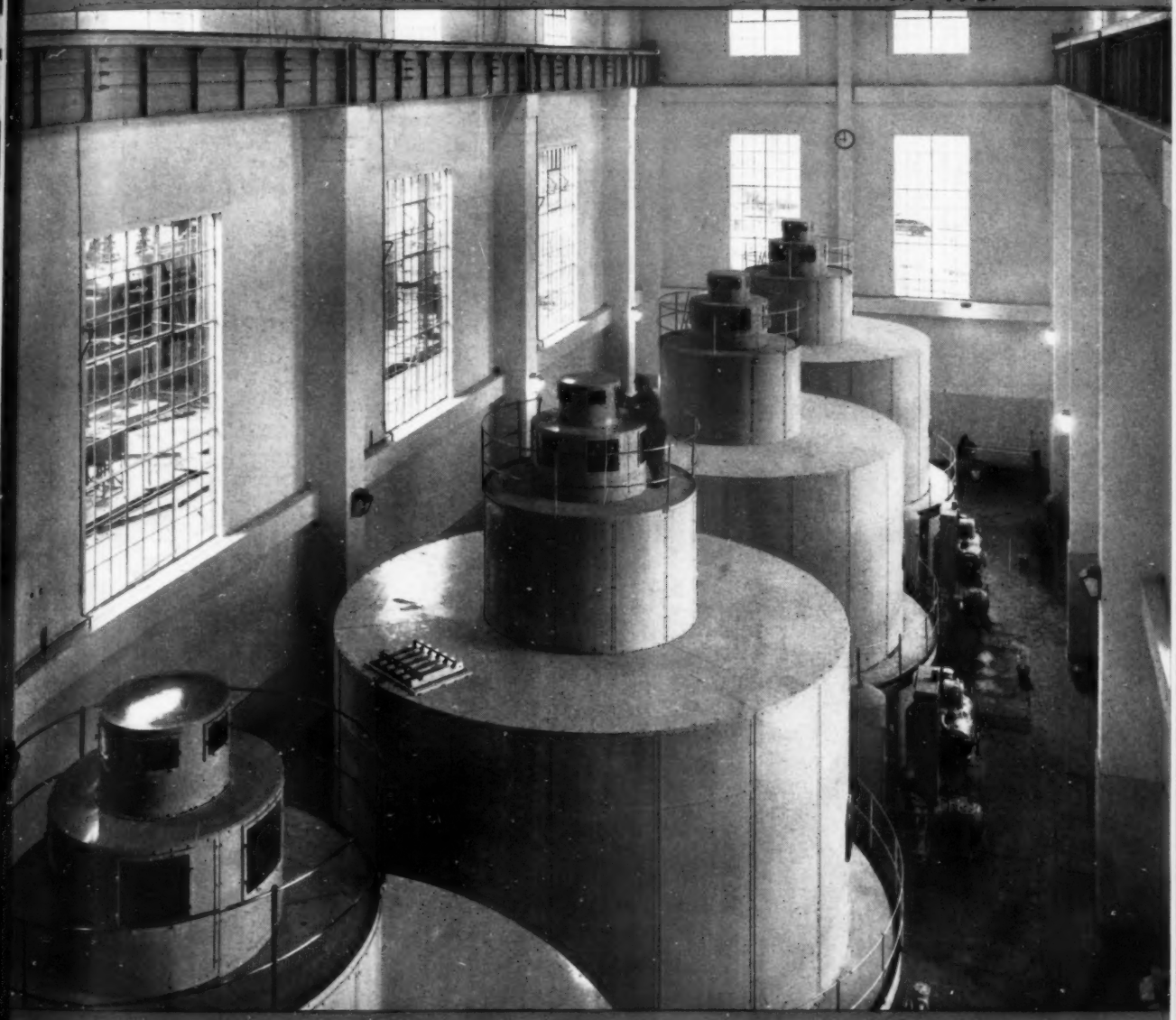
152
31

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

MARCH 1951



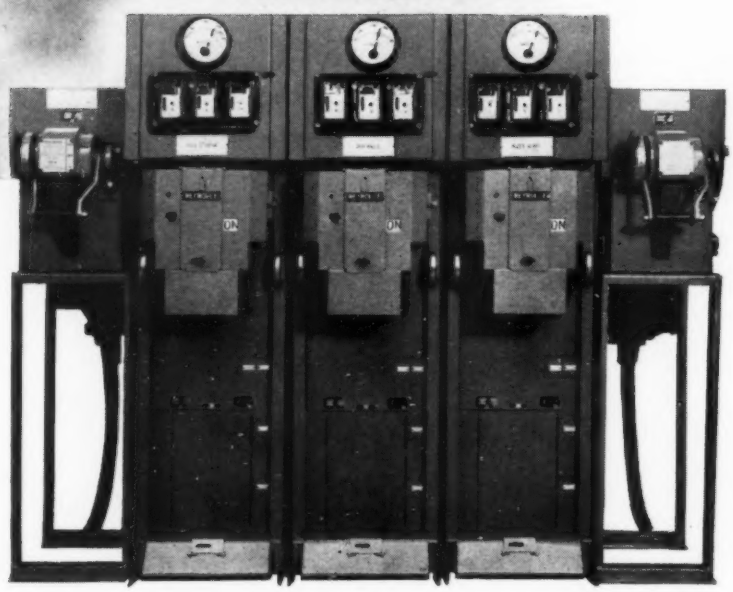
ENGLISH ELECTRIC'
ydro-electric power

Power for half a city

The controlled energy of Loch Sloy drives four 'English Electric' water turbines, each of 45,000 h.p. and coupled to a 32,500 kW alternator. 'English Electric' power transformers and 132 kV Switchgear control the distribution of power — enough for half the peak demand of a city as large as Glasgow. Loch Sloy is typical of complete hydro-electric schemes installed by 'English Electric' all over the world.

The ENGLISH ELECTRIC Company Ltd. Queens House, Kingsway, London, W.C.2.
Hydraulic Dept: Stafford.
Works: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL
See also "English Electric" Transformers Advertisement, page 28

VICTORIA FALLS
Southern Rhodesia



TYPE-5LA * 11,000 Volt * 150MVA * DISTRIBUTION SWITCHGEAR

One of a number
of installations
in the Municipality
of LIVINGSTONE

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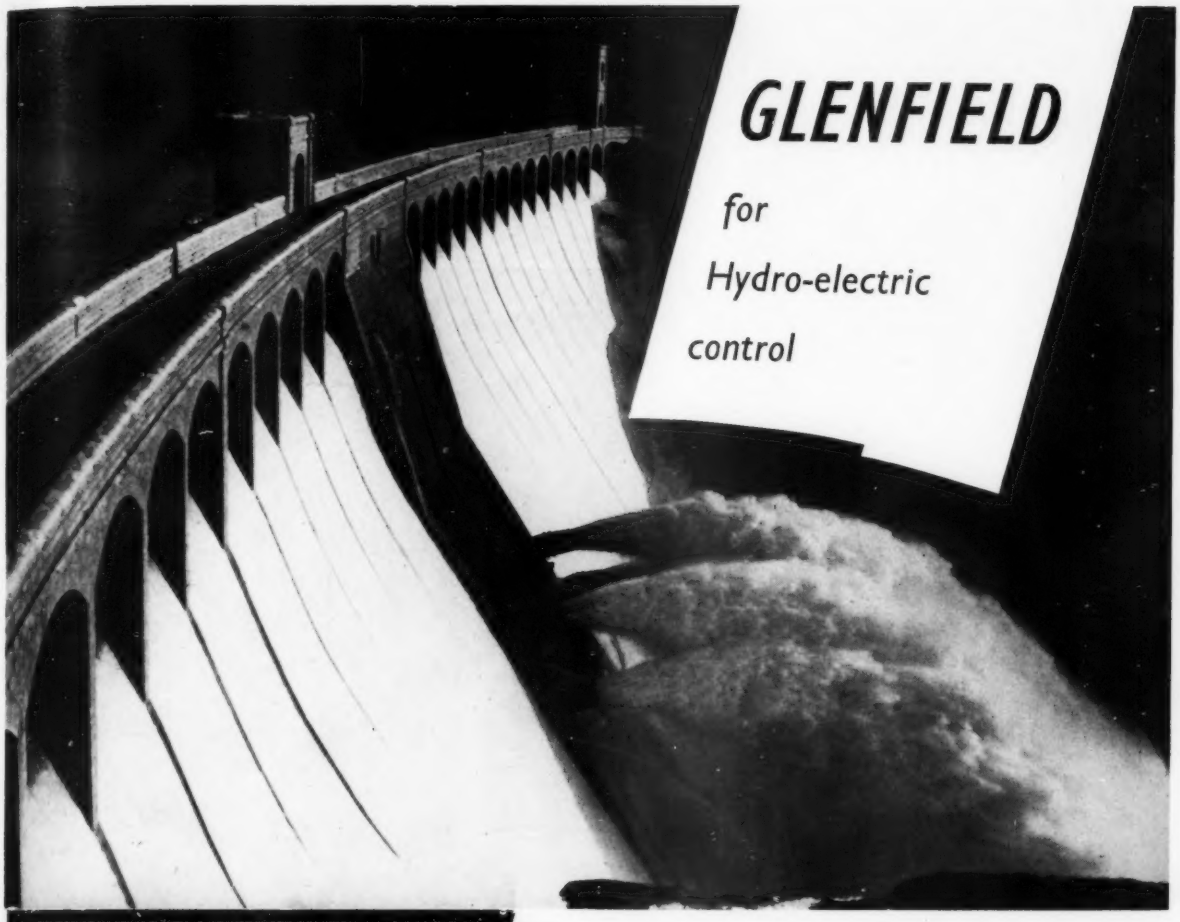
HEBBURN * Co. DURHAM * ENGLAND



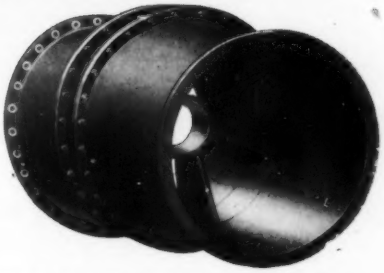
GLENFIELD

for

Hydro-electric

control

JET DISPERSERS



GLENFIELD JET DISPERSERS are in use throughout the world on points of free discharge.

On siphon spillways, scours and on compensation water outlets from dams and reservoirs, and washouts from pipelines.

To result in the harmless dissipation of the issuing jet, without vibration or erosion either of the disperser itself or of the area on which the discharge falls whether into river bed—tunnel—or ditch.

To render elaborate and costly protective works unnecessary.

The top illustration shows six jet dispersers on a siphon spillway each designed to discharge at the rate of 620 cubic feet of water per second to absorb in turn a total of 25,000 H.P. in the process.

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TURBINES

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Lavey Hydro-electric Power Plant
33'650 HP Kaplan Turbine

Ateliers de Constructions Mécaniques de Vevey S.A.
Vevey / Switzerland

Complete Equipment for Hydro-electric Power Plants

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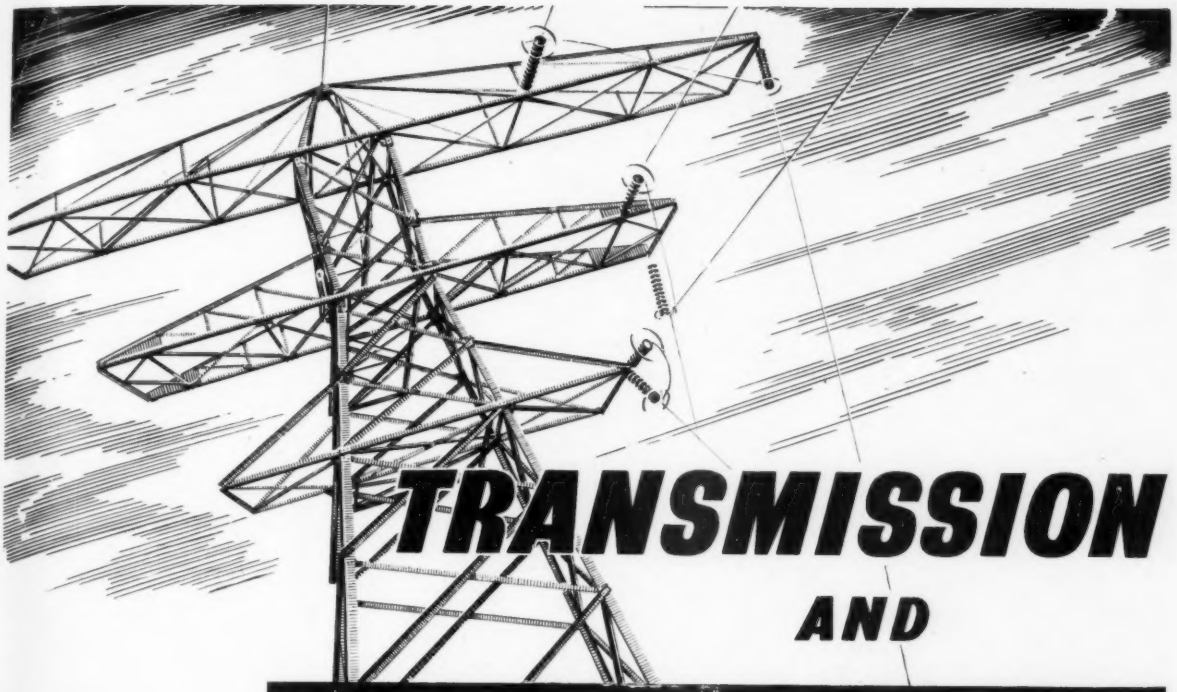
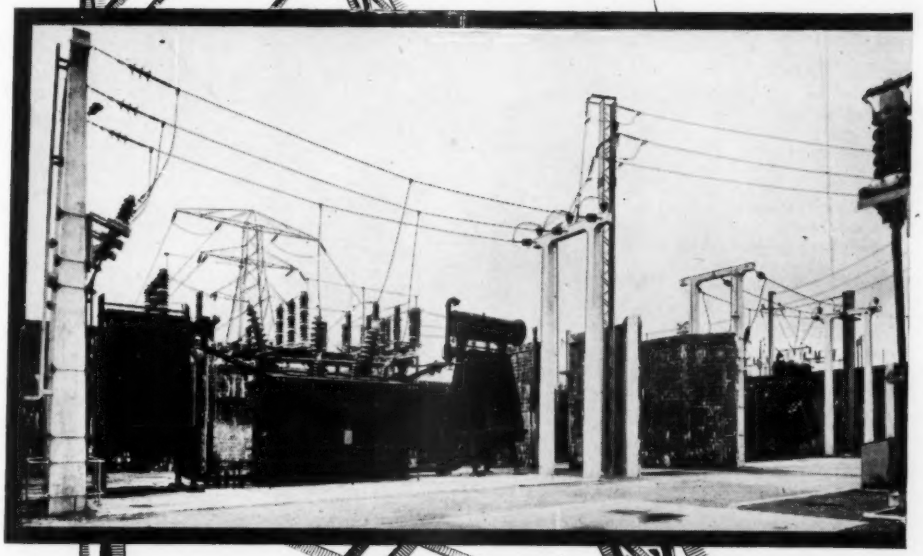


TRANSMISSION AND TRANSFORMERS



by G.E.C.

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AERIAL CABLEWAYS

Henderson Aerial Cableways have solved the problem of raising, transporting and depositing concrete, shuttering and other materials for the construction of large Dams and Barrages.

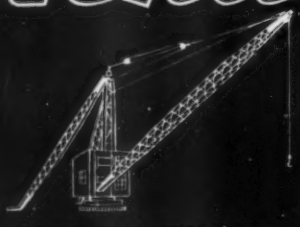
Henderson Cableways are being used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

DERRICK CRANES

Henderson Cranes are chosen so often because of their speed and versatility in lifting materials. Their safety and economy in operation are also assured. Supplied to many leading contractors Henderson Derrick Cranes of all types and capacities can be manufactured for steam, electric, petrol or diesel drive. Cranes can also be fixed or travelling types. Normal sizes are from 10 cwt. to 60 tons Load capacity. With jibs up to 120 feet.

View of Henderson Cableways during the construction of the Claerwen Dam, courtesy of the Birmingham Corporation Water Works. Contractors Messrs. Edmund Nuttall Sons & Co., Ltd

Henderson

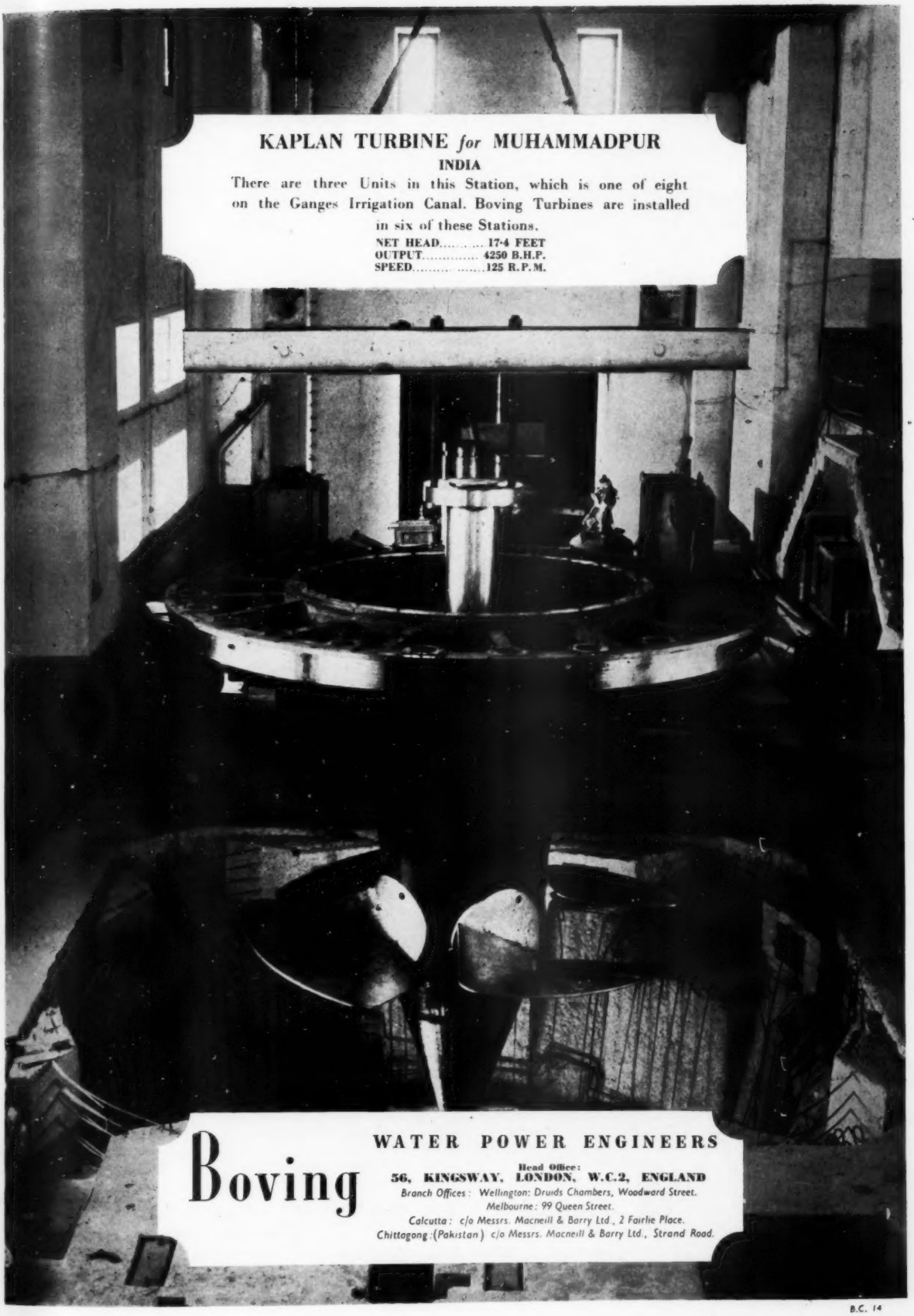


Aerial Cableways

AND DERRICK CRANES

FOR HYDRO ELECTRIC SCHEMES

JOHN M HENDERSON AND COMPANY LIMITED KING'S WORKS ABERDEEN


KAPLAN TURBINE for MUHAMMADPUR
INDIA
There are three Units in this Station, which is one of eight on the Ganges Irrigation Canal. Boving Turbines are installed in six of these Stations.
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OUTPUT..... 4250 B.H.P.
SPEED..... .....125 R.P.M.
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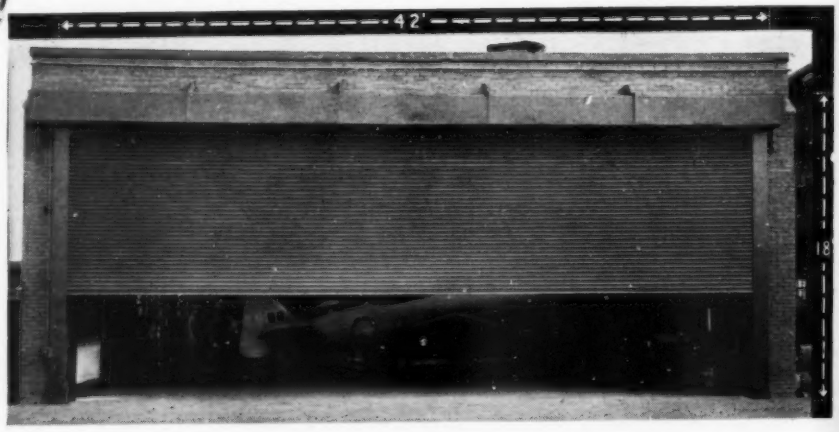
Chittagong: (Pakistan) c/o Messrs. Macneill & Barry Ltd., Strand Road.

B.C. 14

Like Britain **CANADA CHOOSES BRADY**

Land of unusual attainments, Canada also has unusual requirements, but when the Canadian Car & Foundry Company of Montreal wanted a giant 'rolling door' far beyond the usual specification, it was not beyond Brady. Ordered on January 28th, 1949, it was despatched on July 12th, 1949, and in operation on August 5th, 1949; proof that the Brady organisation can tackle out-of-the-ordinary rolling shutter problems as efficiently as the standard installations which have won 'Brady Roller Shutters' an international grading.

This Brady project, 42' × 18' is an object of interest in Montreal, commercial capital of the Dominion, headquarters of the C.P.R., where it is one of the largest 'rolling doors' ever planned and created.



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CANADA: c/o DAVID C. ORROCK & CO. 1405 Bishop Street, MONTREAL 25.

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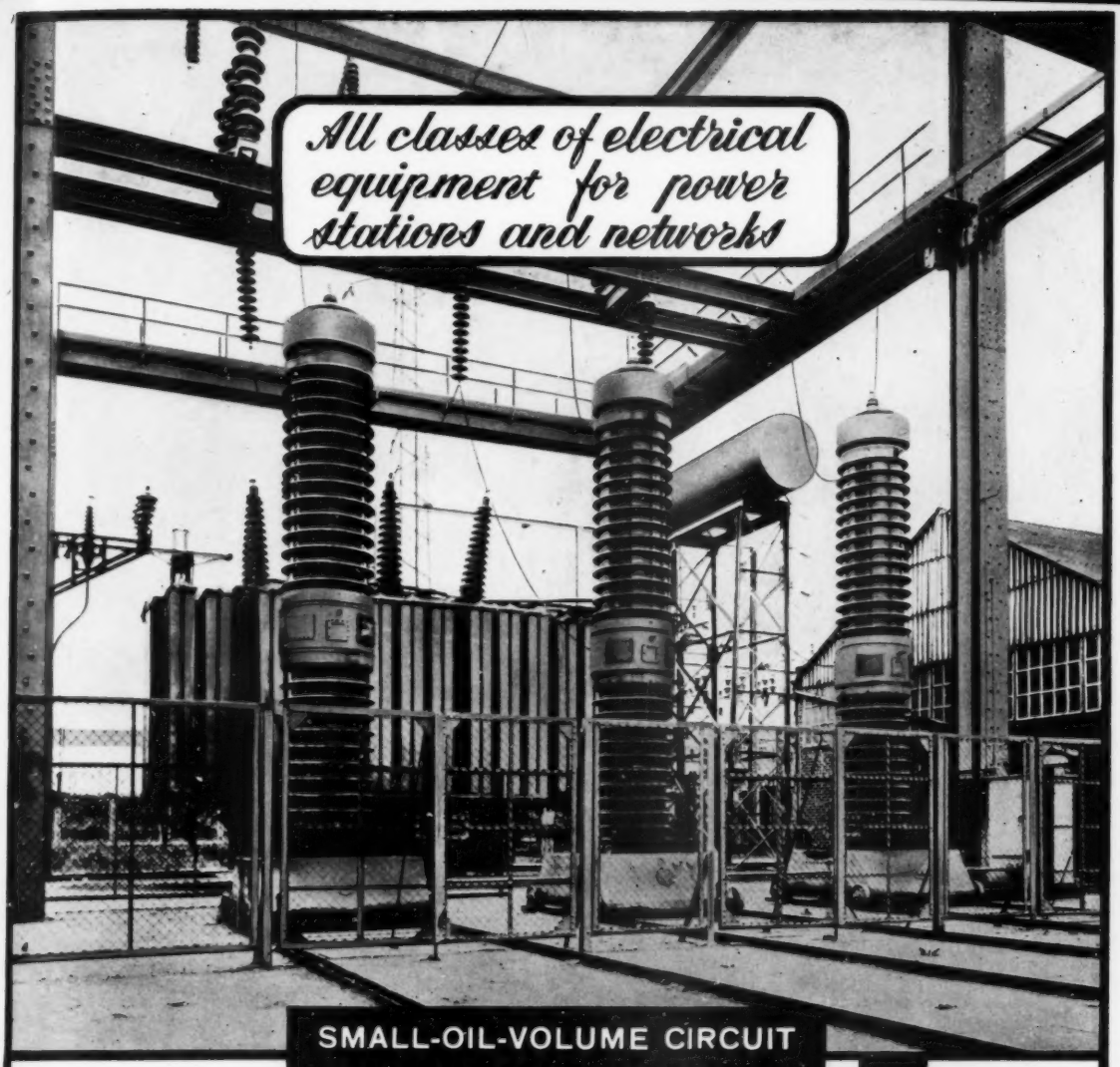


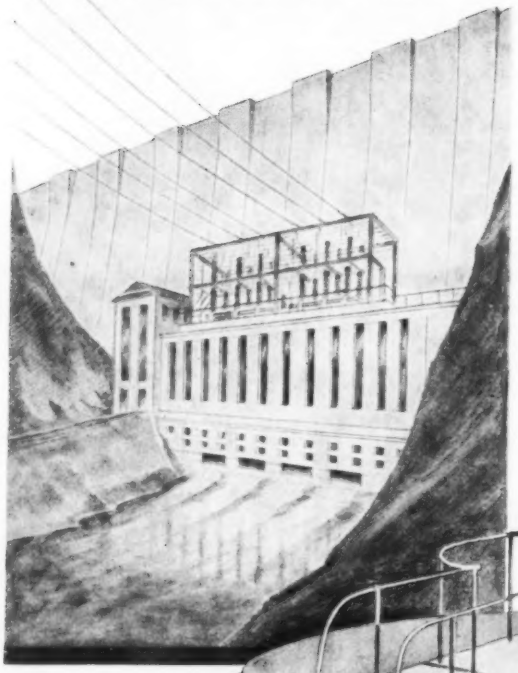
SMALL-OIL-VOLUME CIRCUIT BREAKER TYPE MH. 150 kV.
Installed at the Ville-sur-Haine power station of the Ste d'Electricité du Hainaut (Belgium)

ATELIERS DE CONSTRUCTIONS ELECTRIQUES DE CHARLEROI

CHARLEROI (BELGIUM)

CHARLEROI CAC

Hydro-Electric Plants



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Water-Wheel Generators

60 YEARS' Experience in Hydro-Electric Plants

ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT

Berlin-Grunewald — Export Department — Frankfurt a. M.

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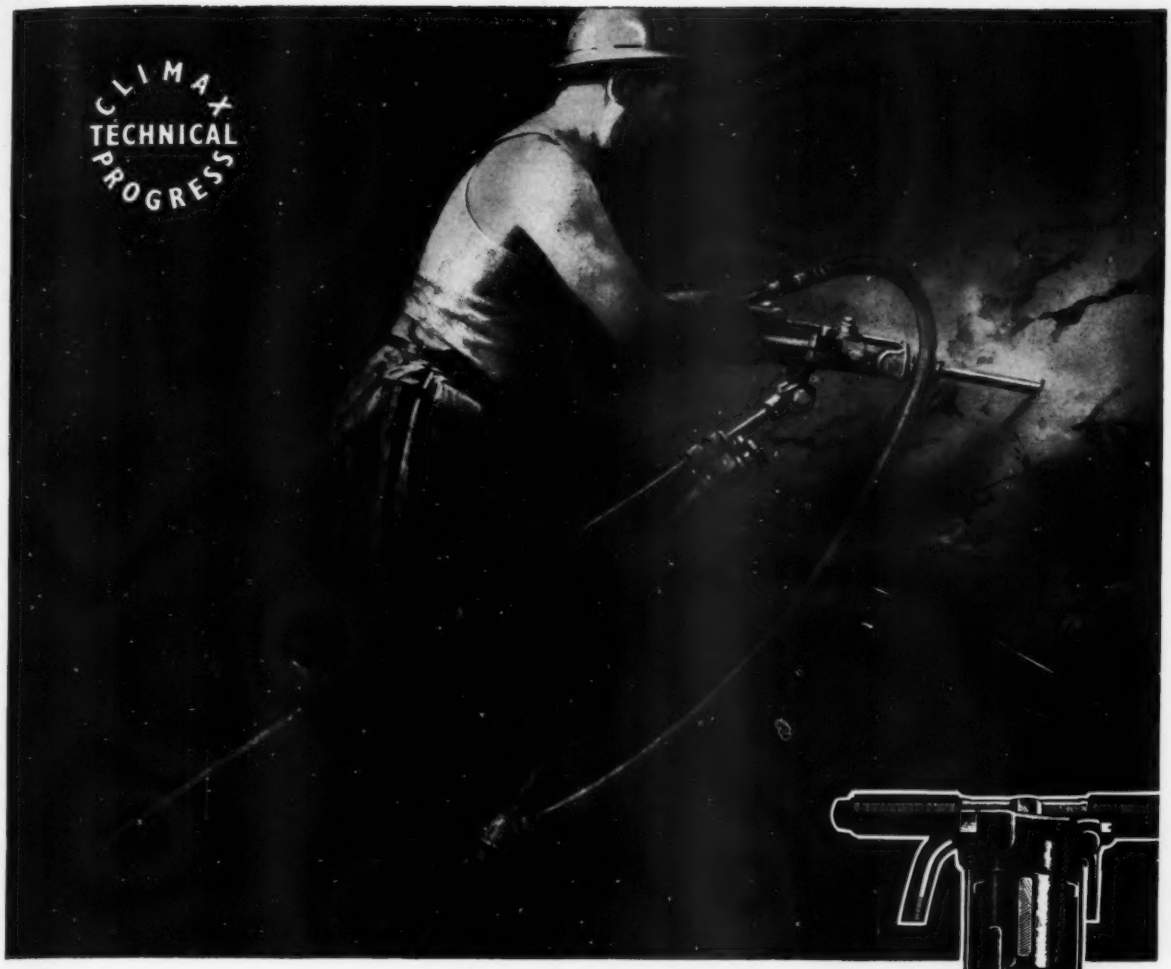

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The R.V.240—a rapid-striking drill specially designed for use with Tungsten Carbide bits**—does the drilling, the "Maxleg" does the supporting and the operator escapes fatigue; which is the economical way of using both men and machines. Holes can be drilled in any position (even right down on the ground) and in the hardest rock with the same ease. As to speed, the pneumatic feed of the "Maxleg" ensures not only more accurate but also much faster drilling than is possible by hand.**

The R.V.240-MAXBIT combination used with the "Maxleg", ensures increased efficiency all round.

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Vast numbers of structural and engineering developments have come to fruition under the jibs of Butters Cranes—operations where the constant flow of materials is vital and where the absolute reliability of the gear is essential.

One of the many, the Ballyshannon Hydro-Electric Scheme (Main Civil Engineering Contractors: Messrs. Cementation Co. Ltd., Doncaster) is illustrated, showing two of several Butters Derricks which were employed.

We will be pleased to submit details of our standard range or to quote against requirements.

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& CO., LTD.

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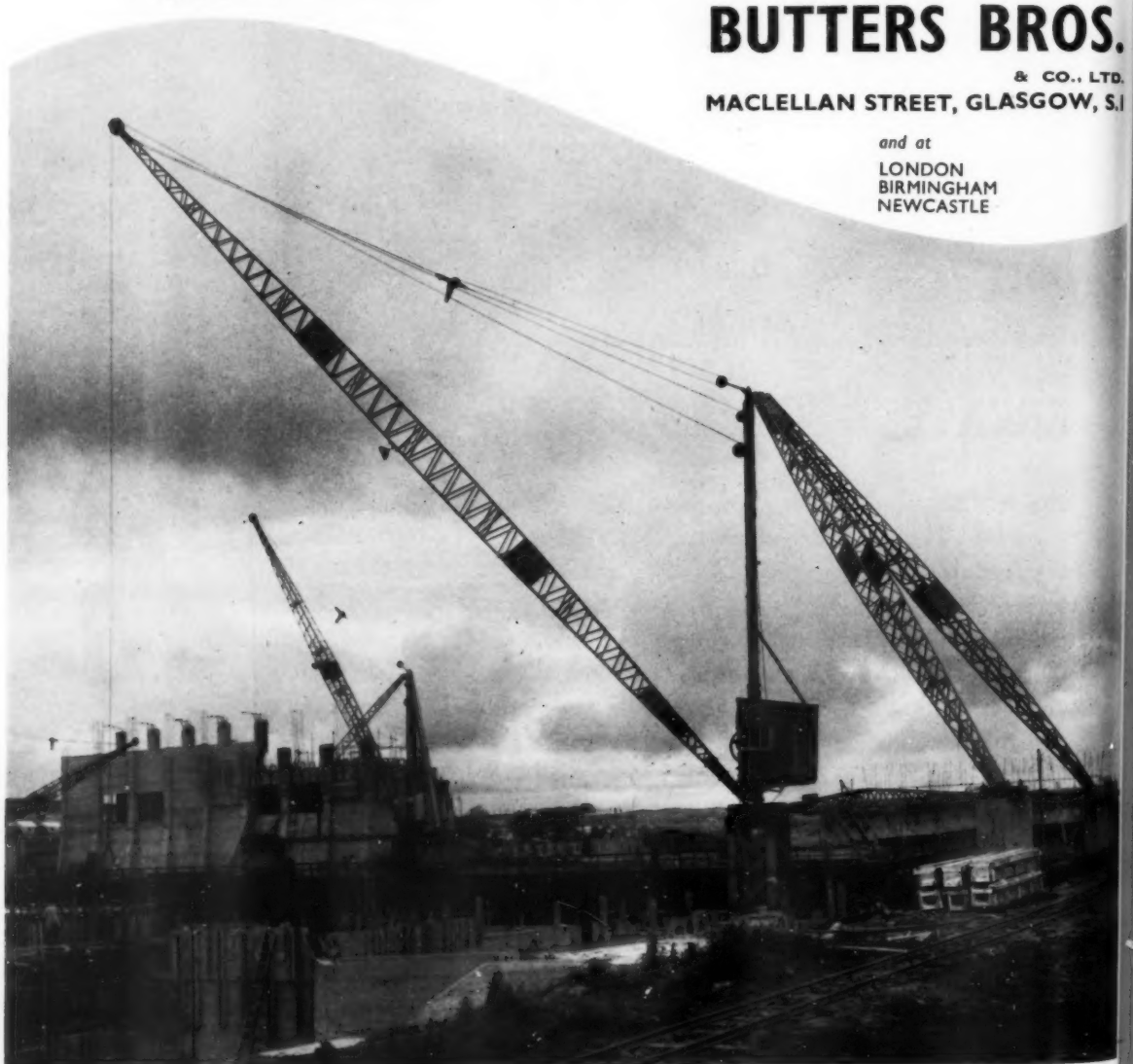
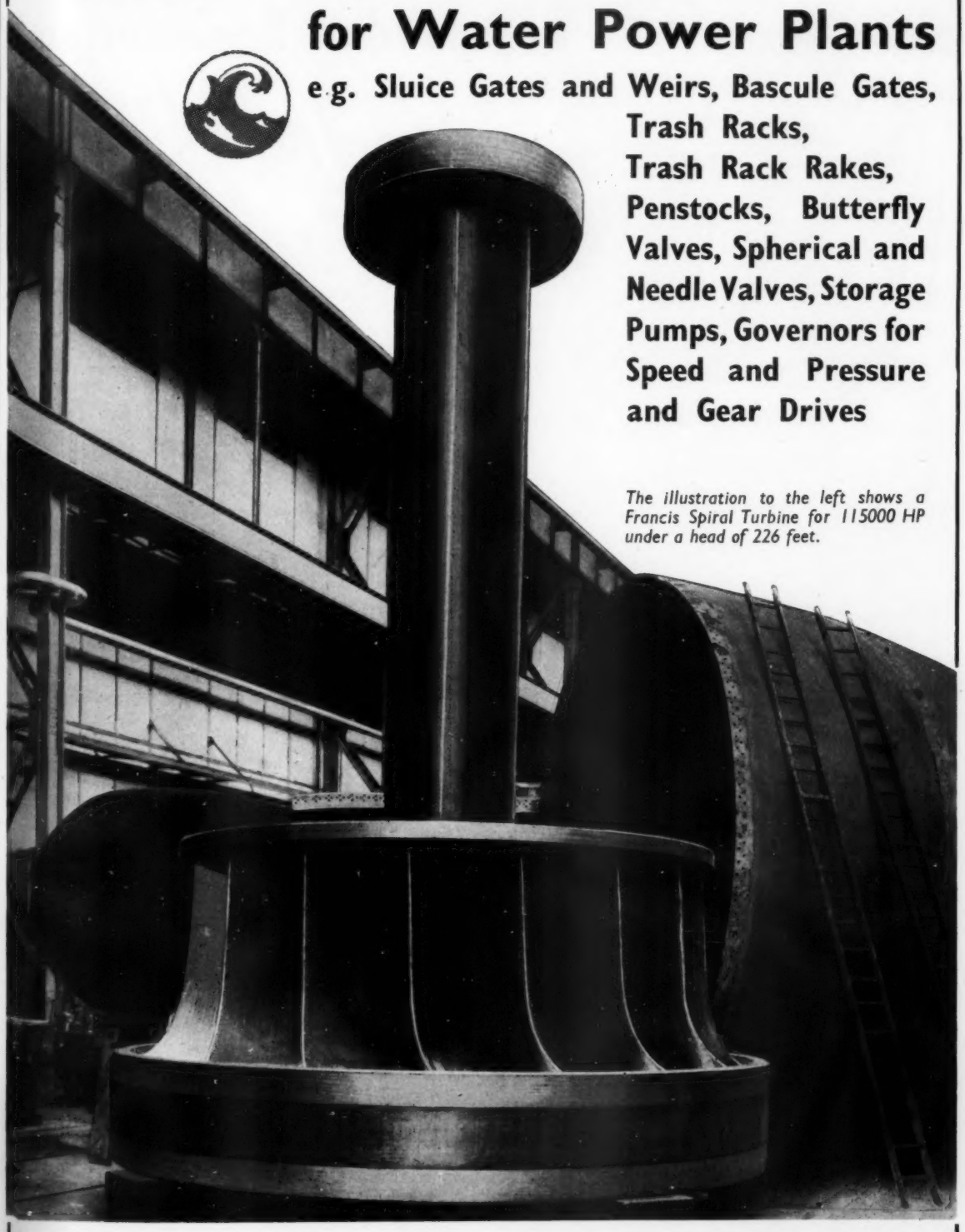


Turbines and Accessories for Water Power Plants

e.g. Sluice Gates and Weirs, Bascule Gates, Trash Racks, Trash Rack Rakes, Penstocks, Butterfly Valves, Spherical and Needle Valves, Storage Pumps, Governors for Speed and Pressure and Gear Drives



The illustration to the left shows a Francis Spiral Turbine for 115000 HP under a head of 226 feet.

J. M. VOITH G.m.b.H., Engineering Works, Heidenheim (Brenz) Germany

15.1.1951 Hlr/Gö

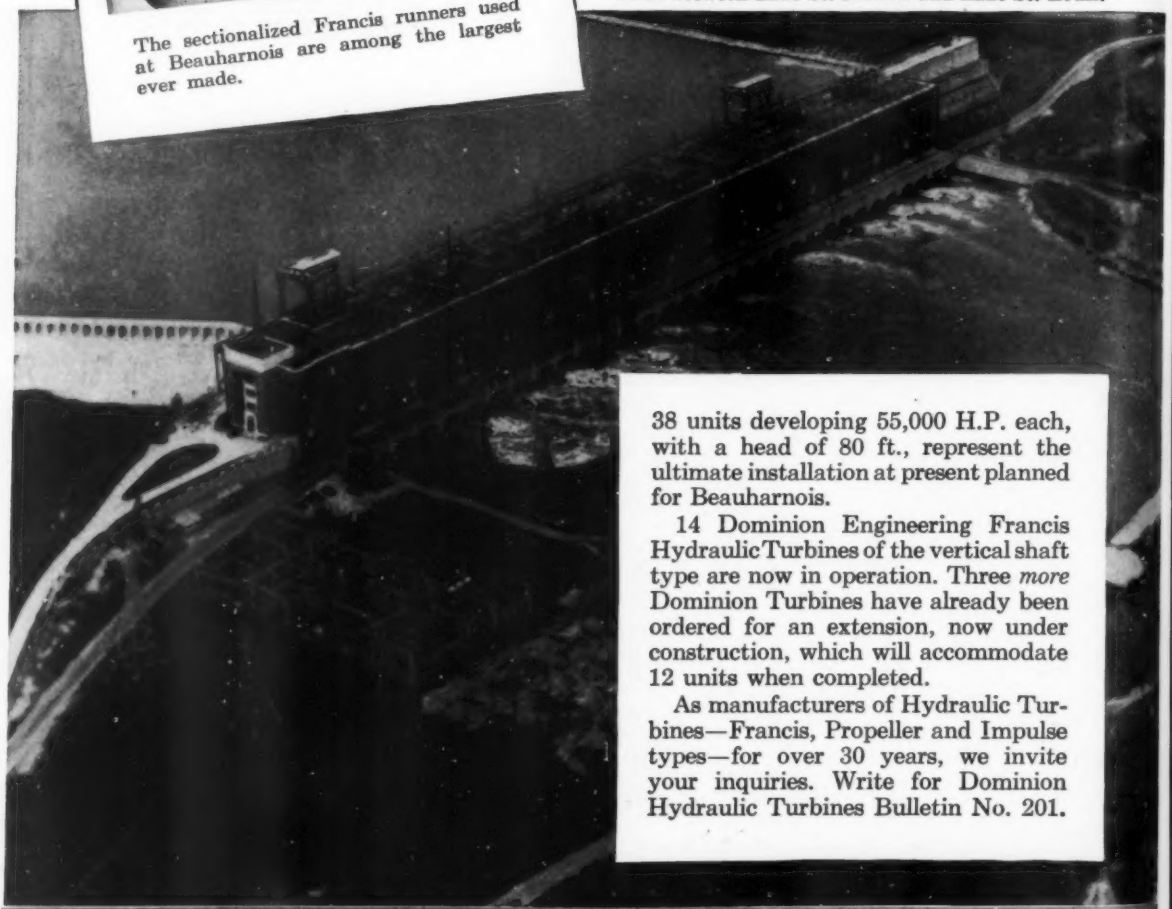
Ultimate Development of over 2,000,000 H.P. in one Canadian Plant

Dominion Engineering

Hydraulic Turbines

The sectionalized Francis runners used at Beauharnois are among the largest ever made.

The Quebec Hydro Electric Commission controlled power installation at Beauharnois near Montreal, at the down stream end of the 15 mile long, three quarter mile wide canal between Lake St. Francis and Lake St. Louis.



38 units developing 55,000 H.P. each, with a head of 80 ft., represent the ultimate installation at present planned for Beauharnois.

14 Dominion Engineering Francis Hydraulic Turbines of the vertical shaft type are now in operation. Three *more* Dominion Turbines have already been ordered for an extension, now under construction, which will accommodate 12 units when completed.

As manufacturers of Hydraulic Turbines—Francis, Propeller and Impulse types—for over 30 years, we invite your inquiries. Write for Dominion Hydraulic Turbines Bulletin No. 201.

DOMINION ENGINEERING

COMPANY LIMITED

MONTREAL, CANADA

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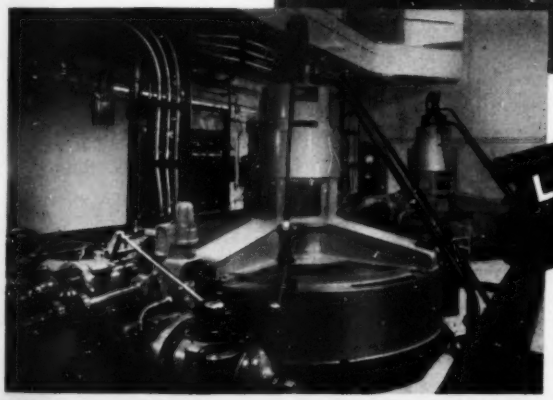
Hydro-Electric Generators

PEEBLES

LOCH FANNICH

13,333 kVA, 11,000 volt, 500 r.p.m. vertical-shaft generator for the Loch Fannich scheme of the North of Scotland Hydro-Electric Board.



LOCH MORAR

LOCHALSH

HORIZONTAL & VERTICAL TYPES

DESIGNED TO INDIVIDUAL SPECIFICATIONS

• • • •

Bruce Peebles are building numbers of hydro-electric generators in sizes up to 24,700 kVA, for various schemes of the North of Scotland Hydro-Electric Board. Views at left show the first two schemes inaugurated by the Board.

Loch Morar : Two 625 kVA, 415 volt, 333 r.p.m.

Lochalsh : Two 625 kVA, 415 volt, 750 r.p.m.

BRUCE PEEBLES

BRUCE PEEBLES & CO. LTD., EDINBURGH, SCOTLAND

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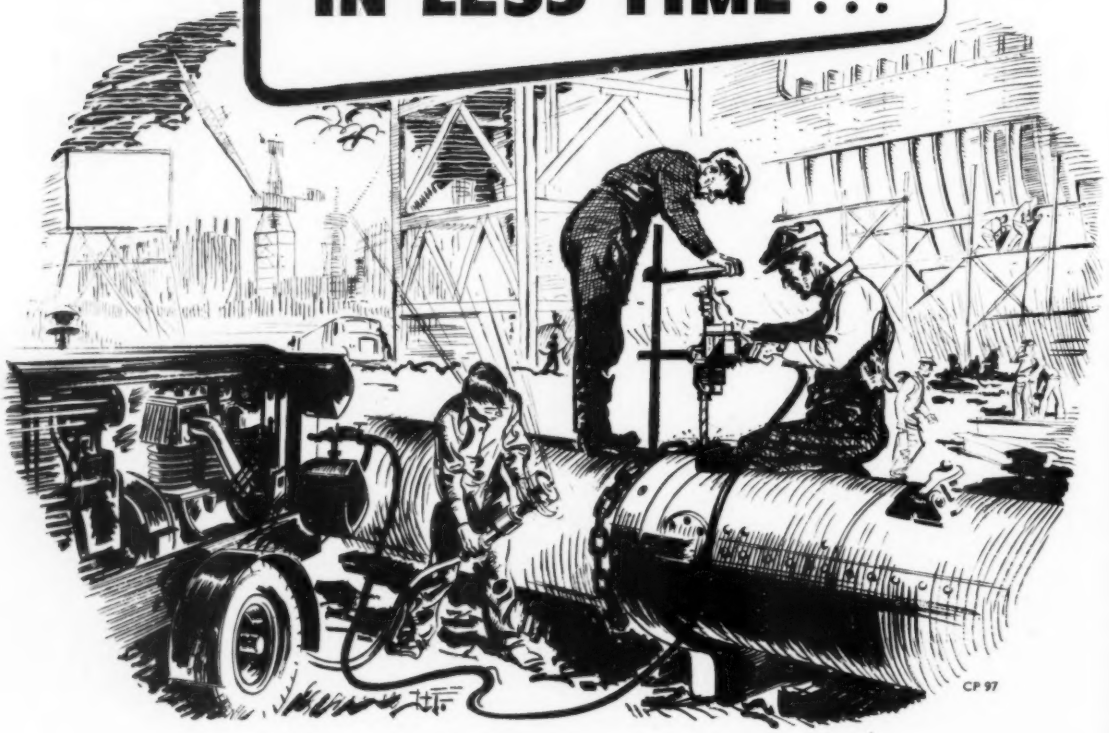
DO MORE WORK IN LESS TIME . . .



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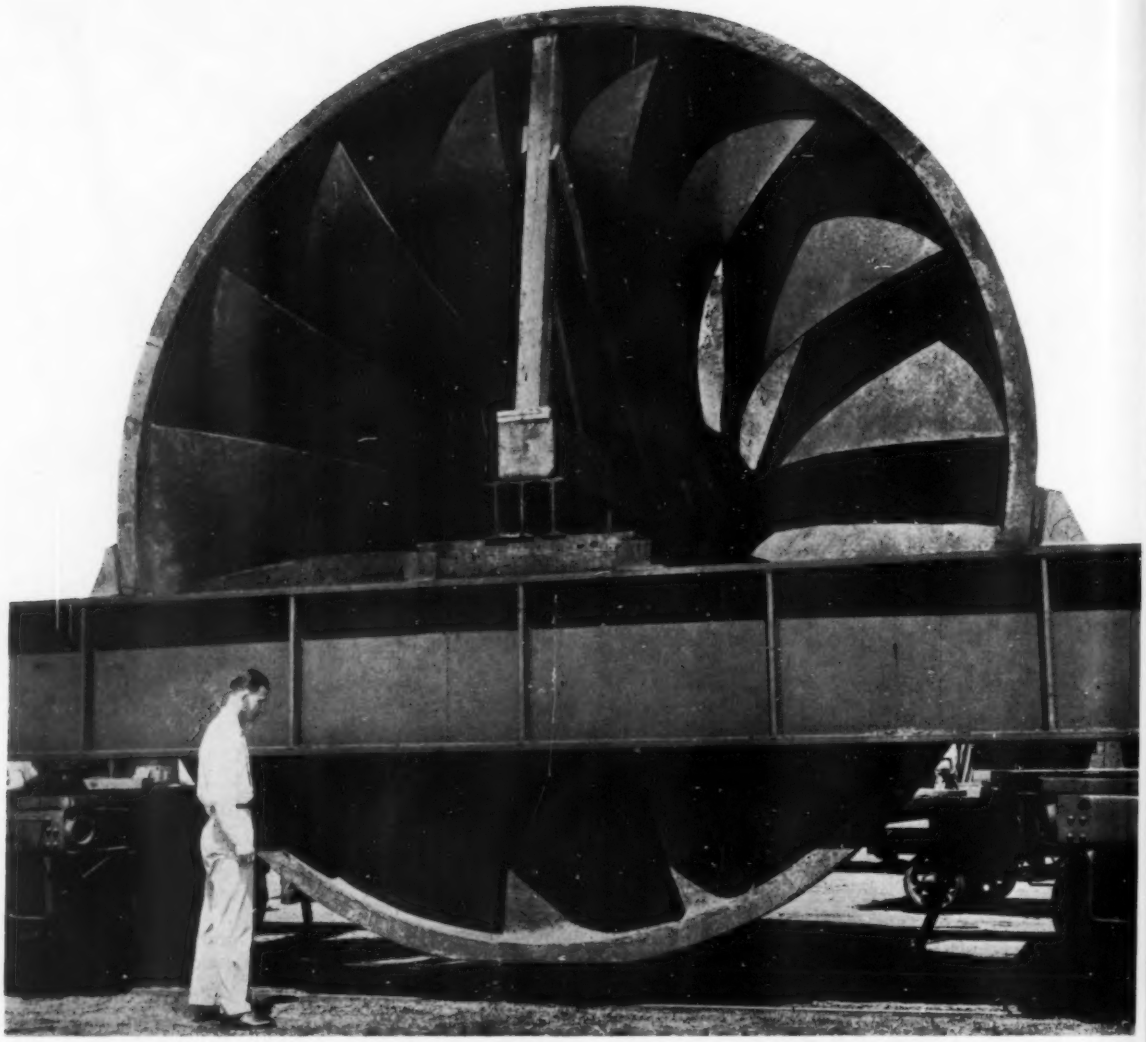

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Supplementing the extensive facilities are the equally important experienced and skilled personnel at Newport News to design and build such equipment.

Your inquiries for hydraulic turbines of any size will receive prompt attention.

Write for illustrated booklet on water power equipment.

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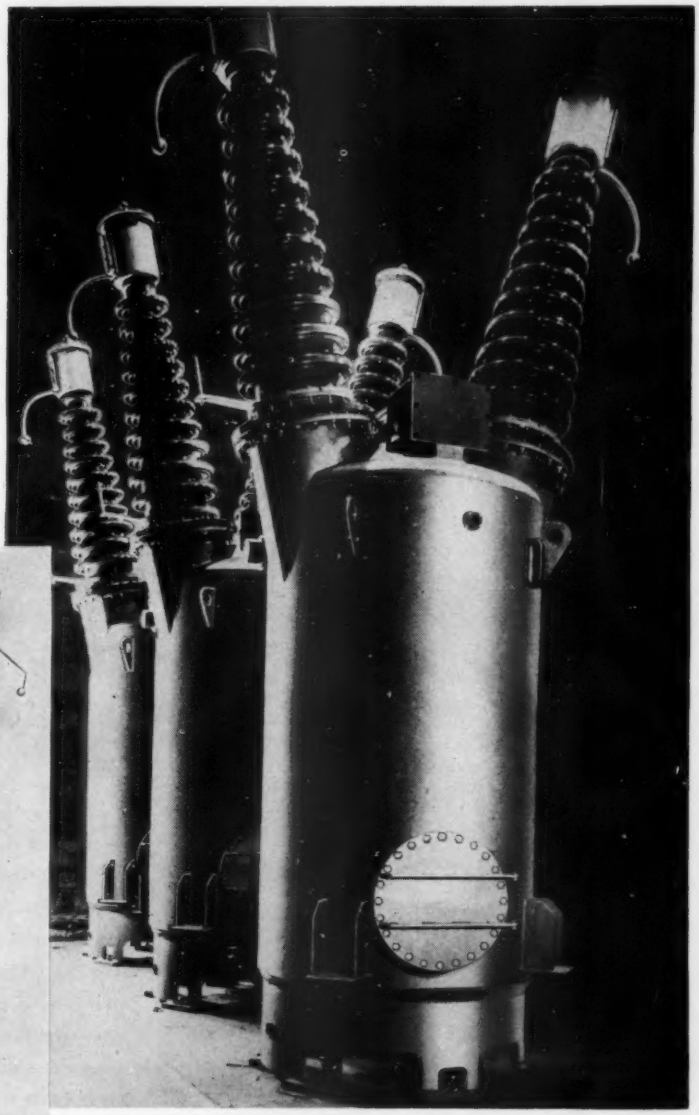
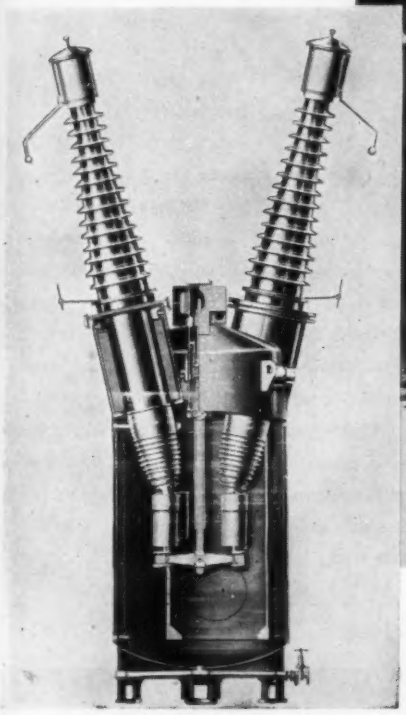
NEWPORT NEWS, VIRGINIA, U.S.A.

Hydro-electric Equipment

132 kV., 3,500 MVA "Shuntarc" oil-break circuit breakers. Thirteen breakers of this class have been supplied to the New Zealand State Hydro-electric Department





Sectional drawing through a single-pole unit showing resistor-shunted self-compensated arc-control chambers

For all plant required for Hydro-electric Power schemes
Consult BTH

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THE BRITISH THOMSON-HOUSTON CO. LTD. WILLESDEN, ENGLAND

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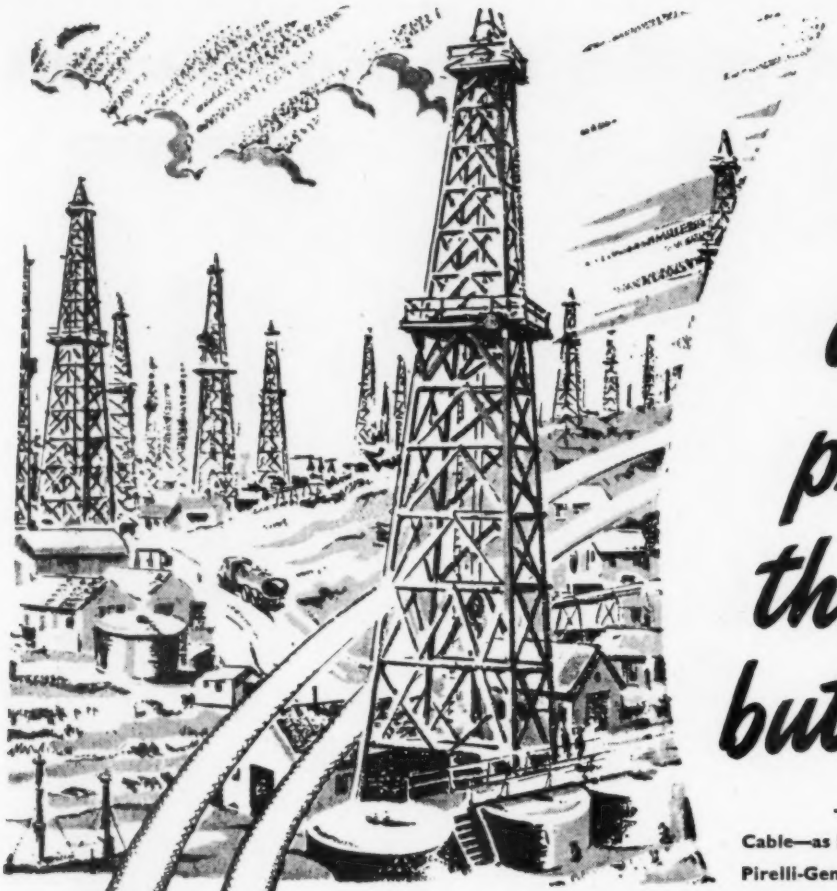

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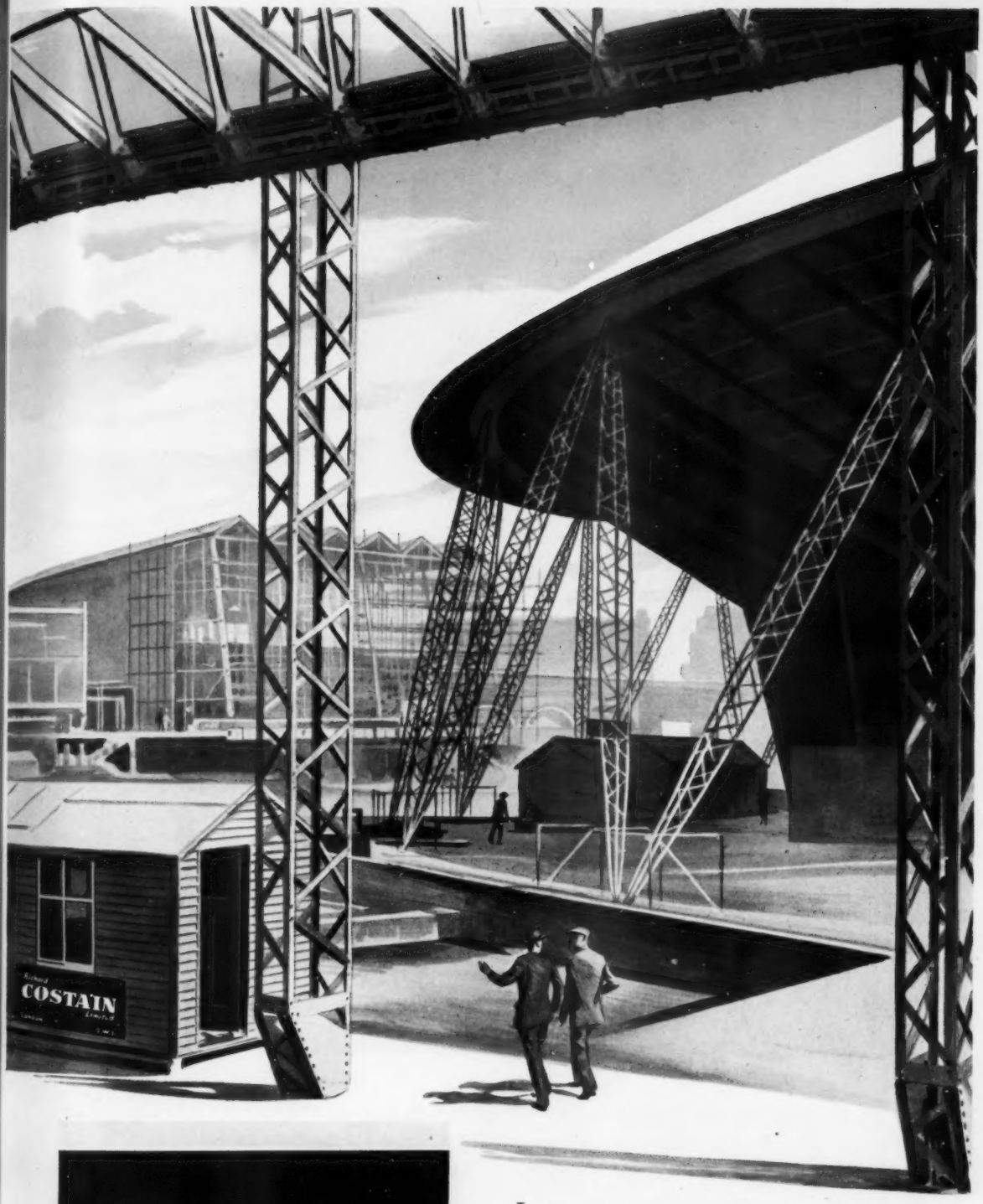

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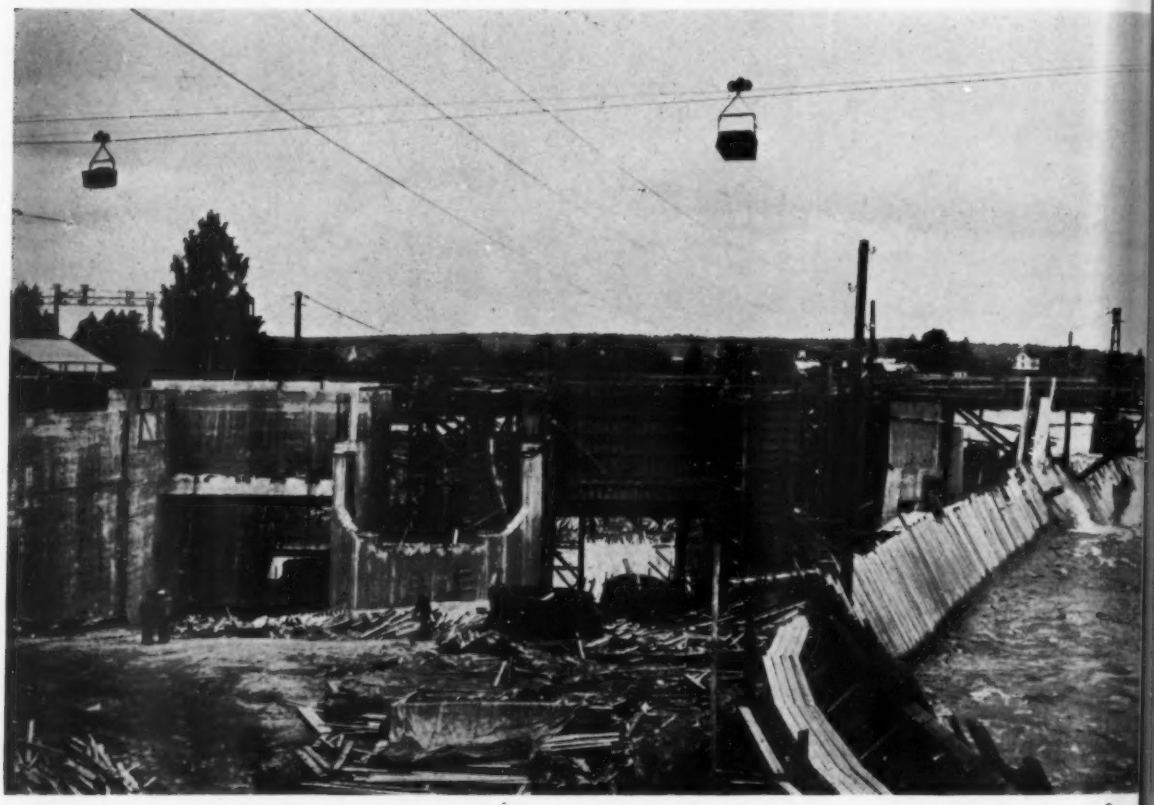

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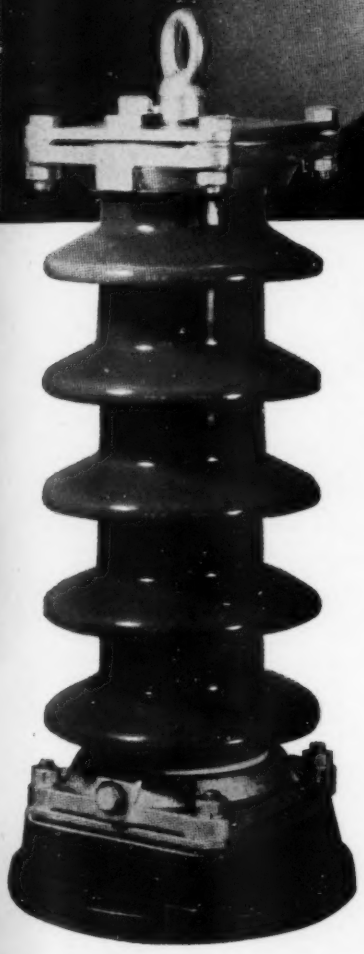

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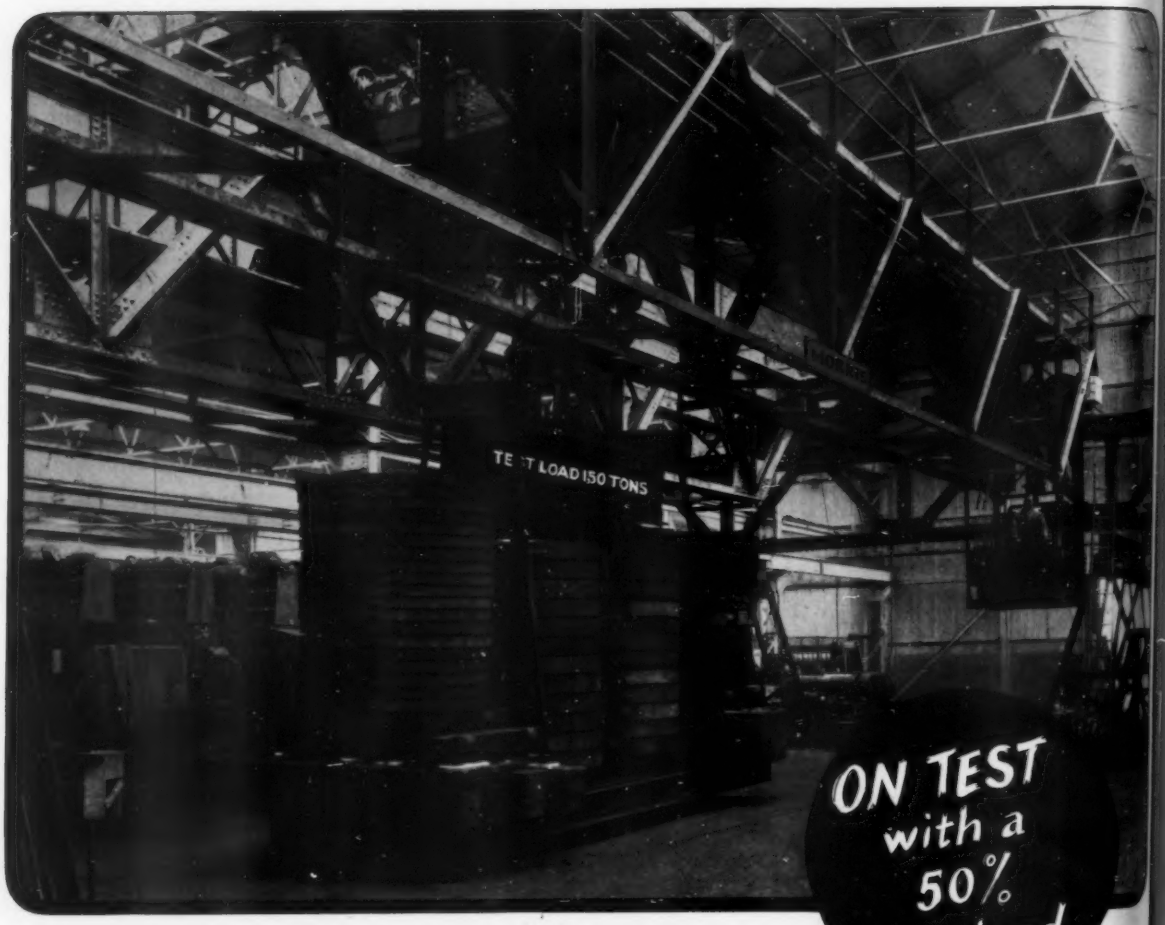

ON TEST with a 50% overload.

HERE is another Morris 100-ton power station crane being tested at our works with a load of 150 tons. For the rapid handling of comparatively light loads, the crab embodies a 15-ton auxiliary hoisting gear; this too was tested with a 50 per cent. overload. The crane bridge has a span of 72-ft. 6-ins. and is mounted on articulated end carriages. Overhead cranes are a vital part of power station equipment, for to them falls the task of lifting the generating plant into position. They must therefore be designed and built with an eye to the work expected of them and above all, they must be dependable. Morris cranes in power stations everywhere uphold a long-standing reputation for dependability.

MORRIS

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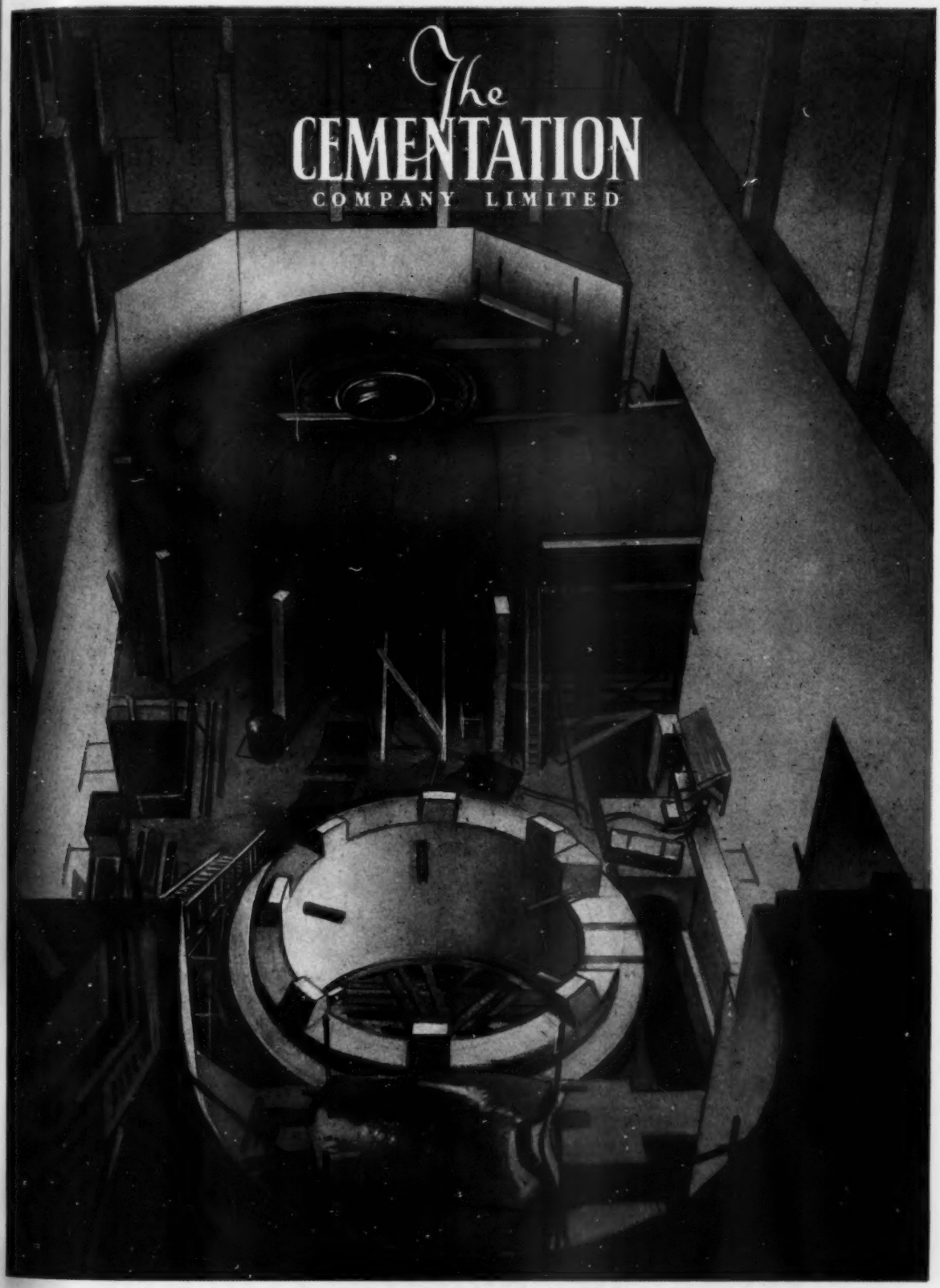

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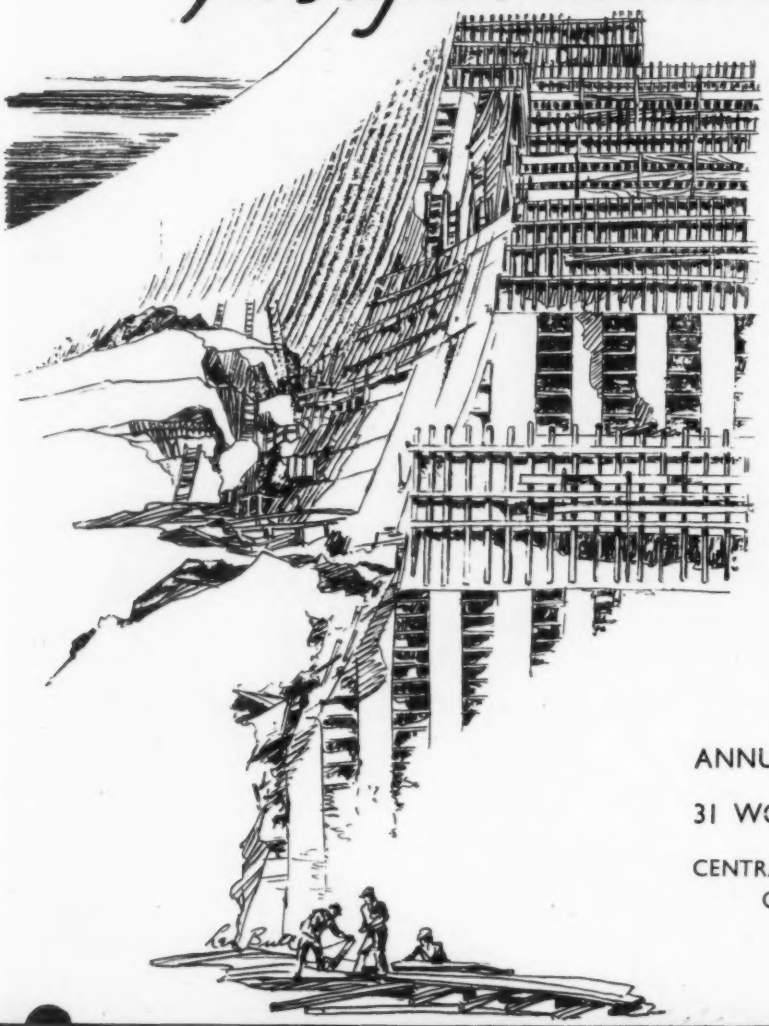

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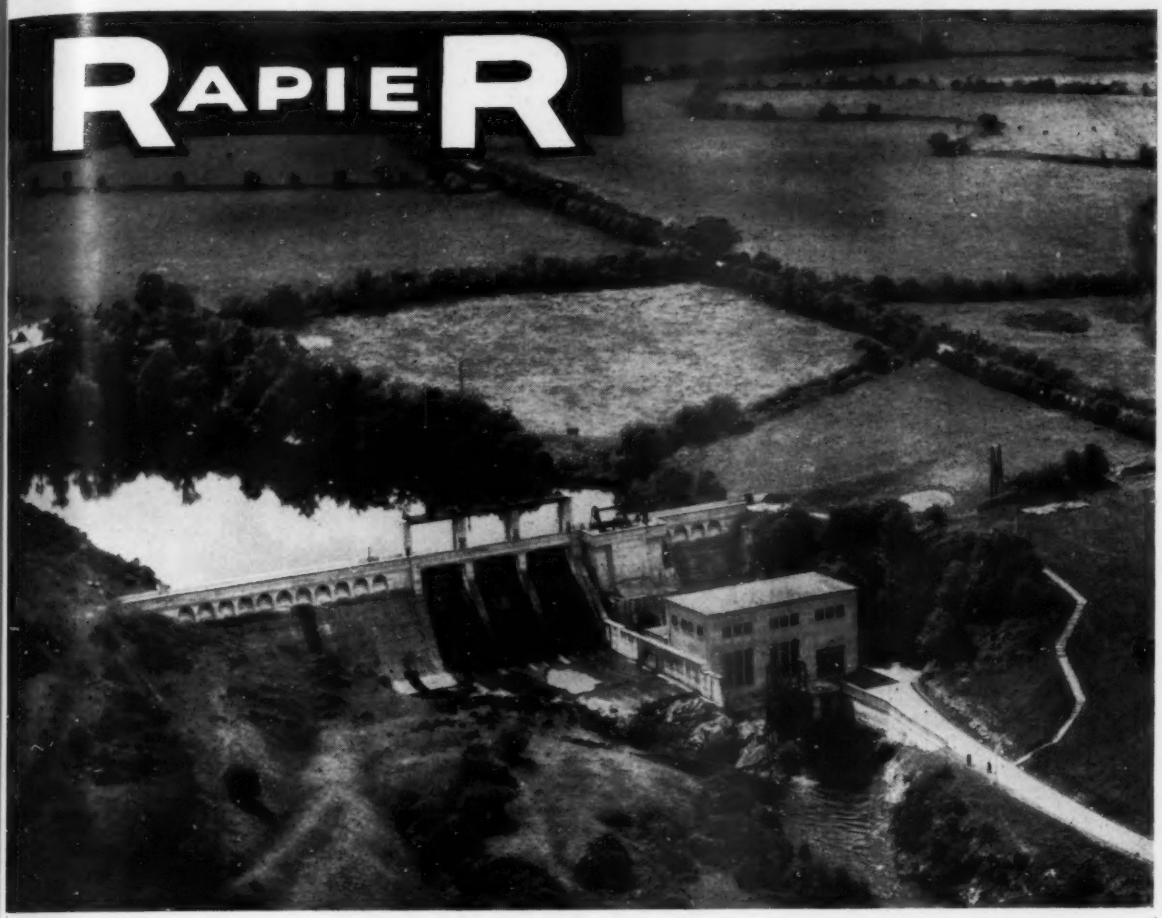

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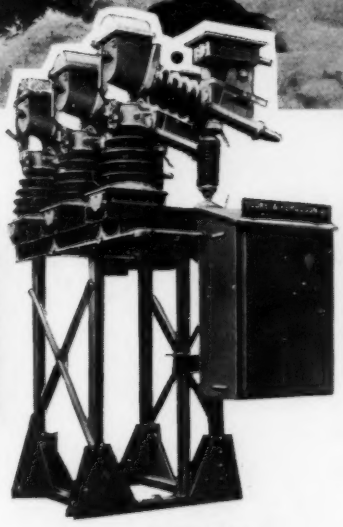

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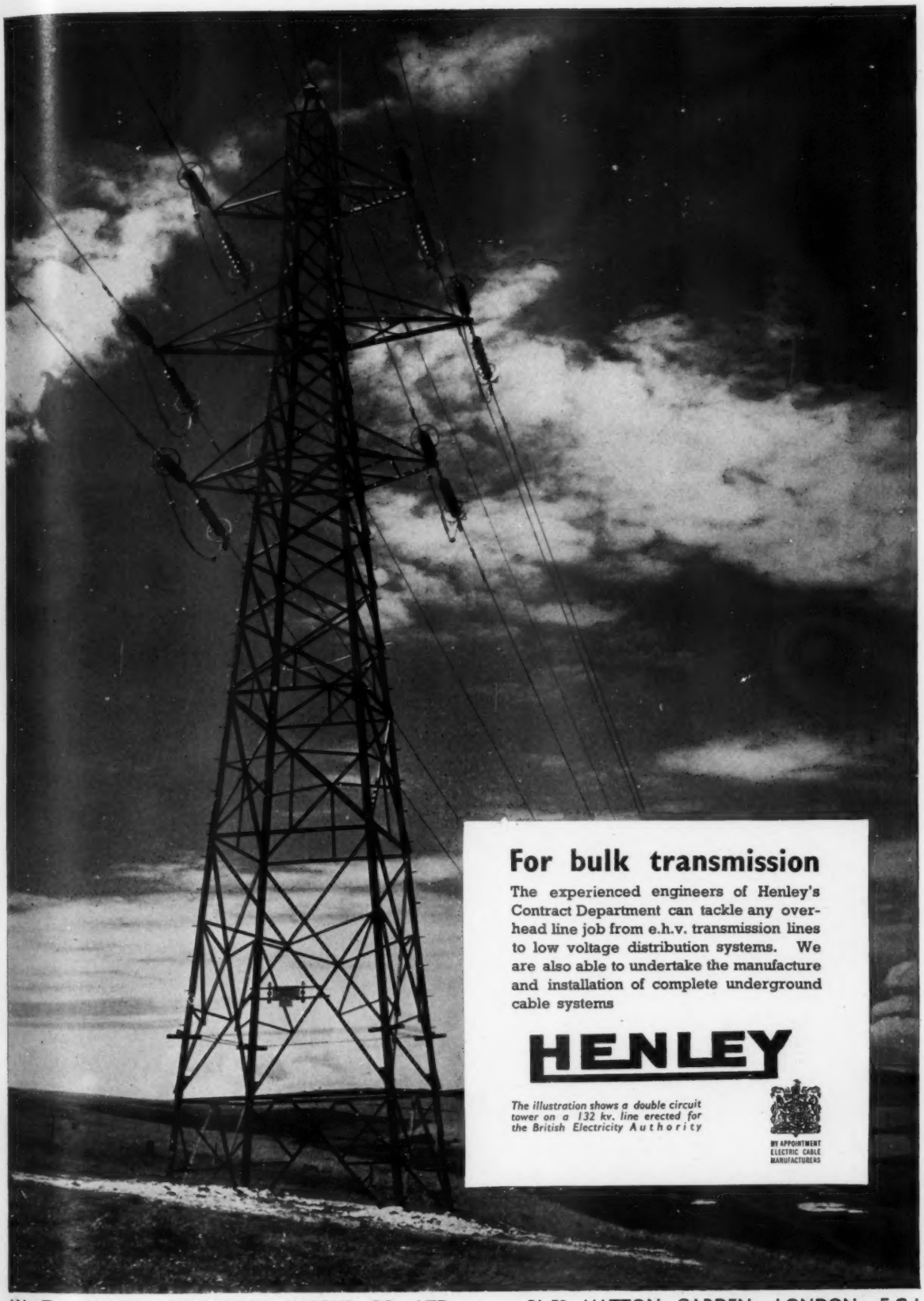

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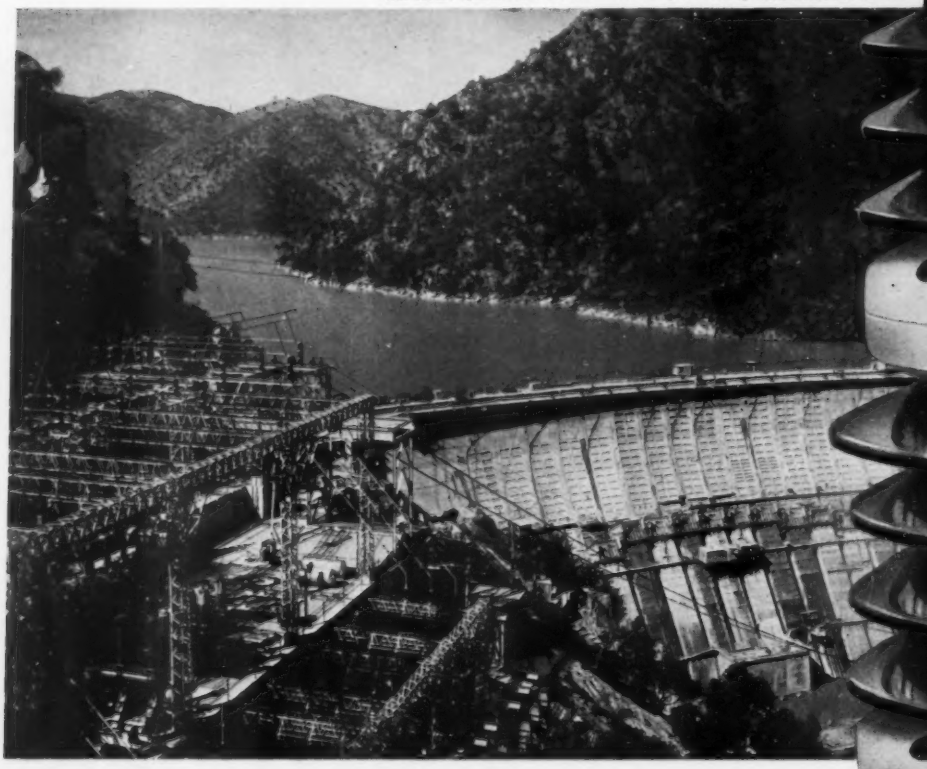

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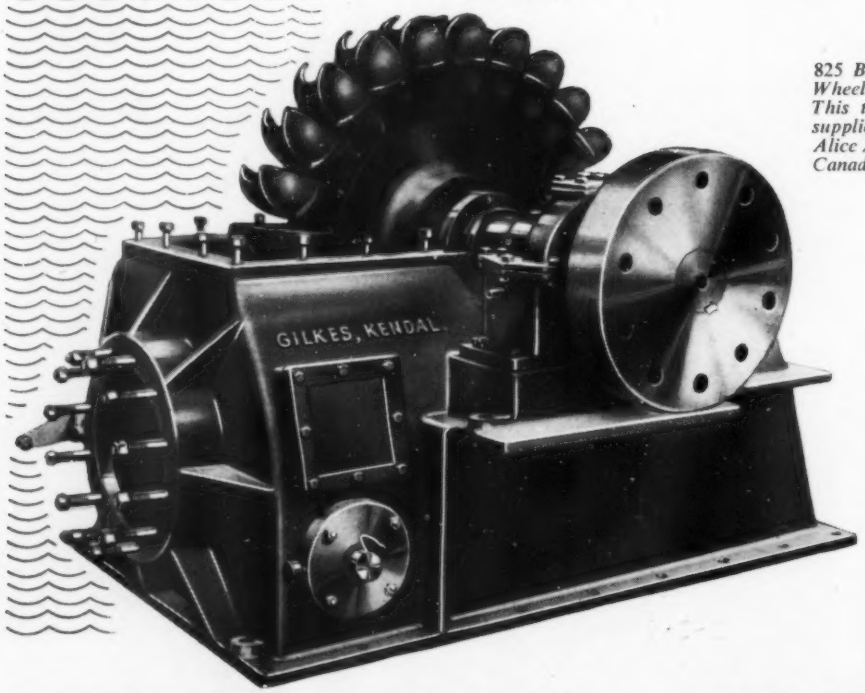

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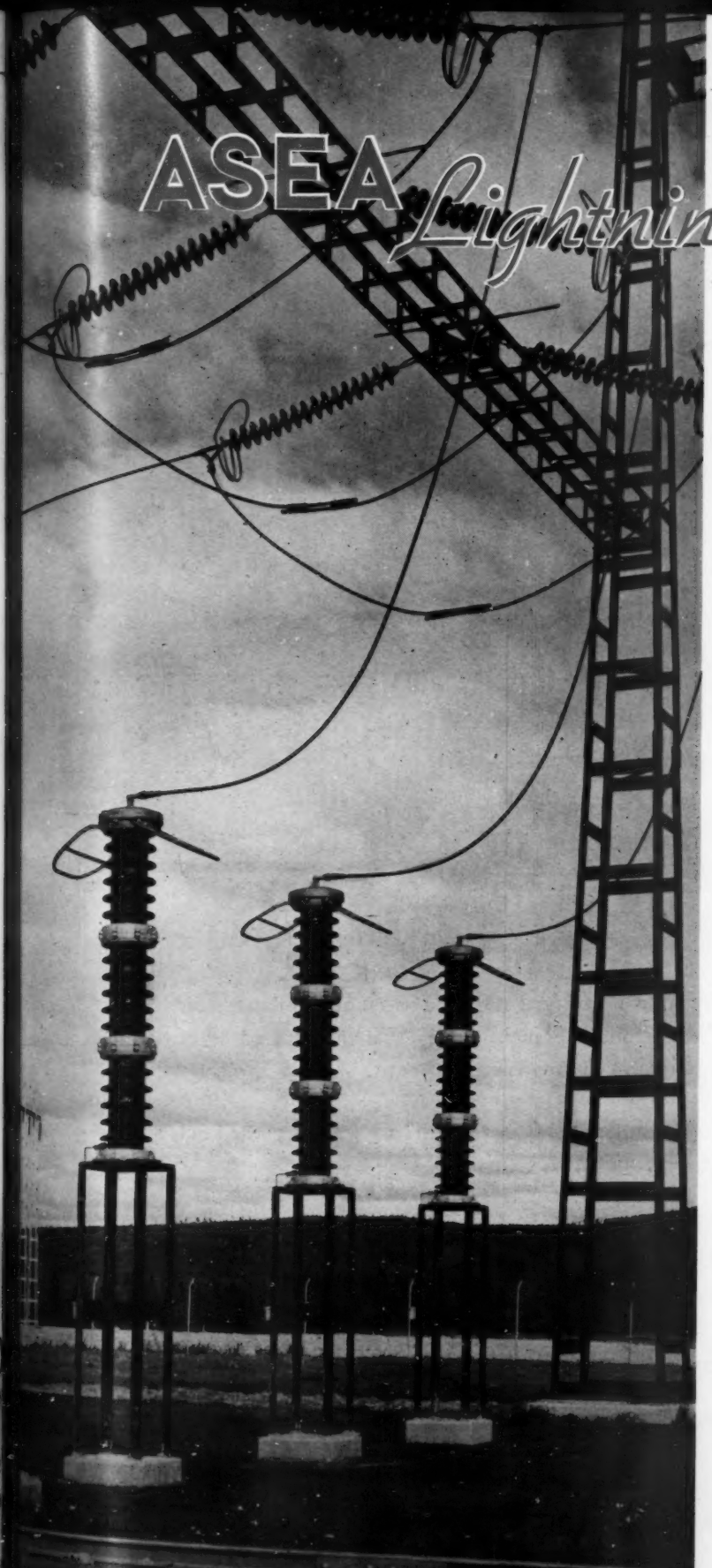

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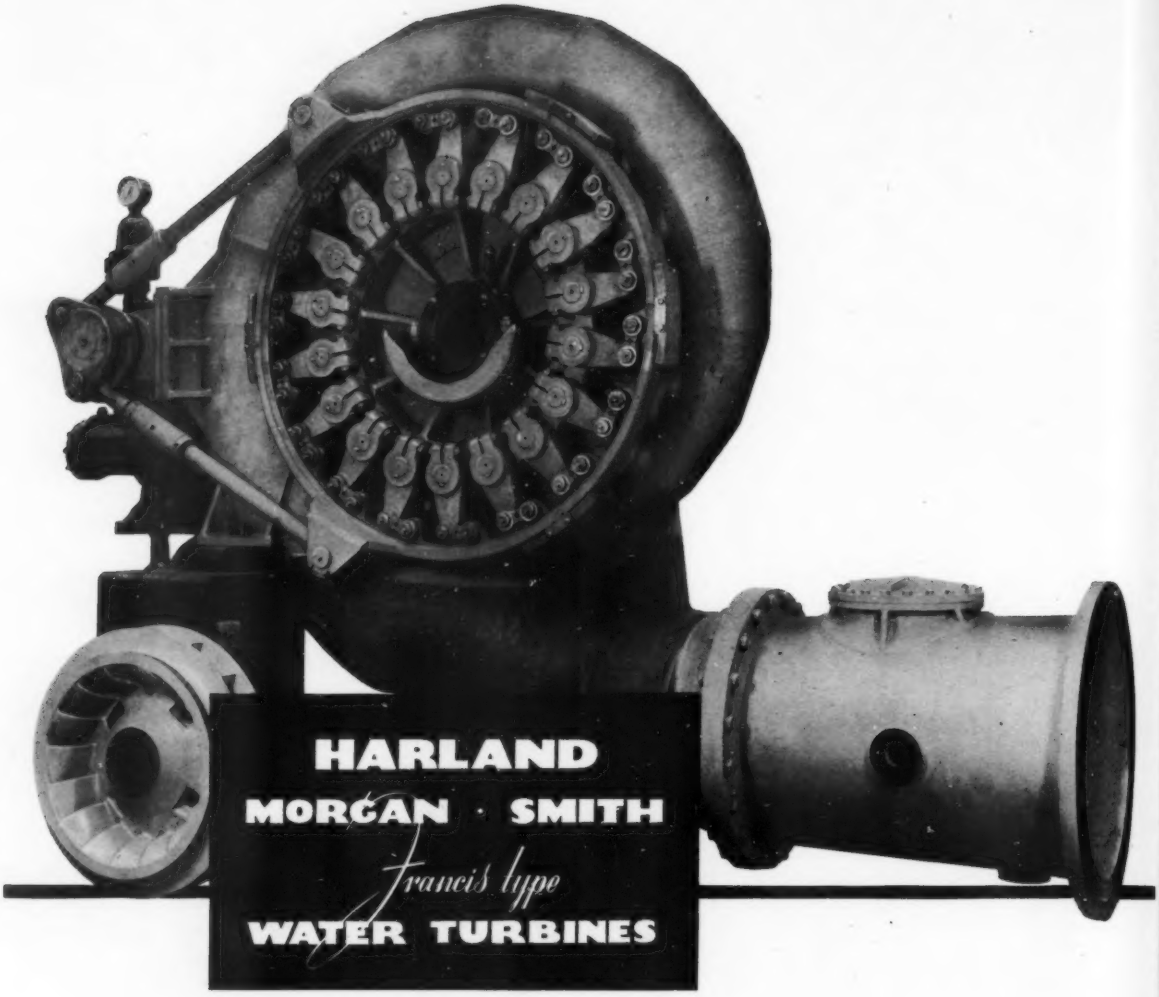

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The Conferences in India

ONE of the significant points in connection with the four conferences held in New Delhi, India —the International Association for Hydraulic Research, the Fourth Congress on Large Dams, the First Plenary Session of the International Commission on Irrigation and Canals, and the Sectional Meeting of the World Power Conference—was that it brought to light, for the first time, the intense interest of the Indian people, and especially their engineers, in power matters in general and hydro-electric power in particular.

This was the first occasion on which highly technical conferences had been held in an Eastern country, and although few other Asian countries were represented, not only the numbers but the quality of the Indian engineers present, and the authoritative nature of their contributions, both in the papers and discussions, marked a new phase in the Westernisation of India.

Those attending the conferences spoke with the utmost gratification of the efficiency with which all the arrangements were carried out—something which cannot always be said of conferences organised even in the most highly developed Western capitals.

Another important factor was the expression by Indian Government speakers of the strongly held view that the time is more than ripe for the establishment of large-scale manufacturing organisations in India. This brings with it the corollary of a vast number of subsidiary industries needed in a complete hydro-electric scheme. It is not sufficient to be able to construct the dam of materials largely found in the country; it is also necessary to have ancillary industries such as highly technical glass factories for the glass used in electrical insulation, and metallurgical equipment to produce the high purity alloys used for the conductors, and a host of other specialised industries. To back this up there must be research, and this research needs, in turn, the steady supply of technically qualified workers, who need colleges, instructors, laboratories, and finance.

The steady stream of Indian engineers who have received their training in Great Britain, America, Switzerland, France, and Sweden, to mention only a few of the leading countries associated with the manufacture of large-scale hydro-electric equipment, has perhaps passed unnoticed owing to the wide distribution of the students. Now that many of them have returned to India and, in turn, have instructed others, it seems that India is fast approaching the position where she will be able to develop her own potential water power by the use of her own labour, her own skill, and her own manufacturing organisations. This may take another decade for such schemes cannot be matured quickly, but by the time the necessary survey work and the long-term civil engineering have been started, it may be that plans for the construction of electrical plant in India will have been brought to fruition. This, at any rate, was the impression gained by some of the delegates, who in addition to attending the conference also embarked on study tours to various hydro-electric plants and manufacturing centres.

All these factors, if international disruptions do not invalidate them, will lead to a reconsideration of the export policy of manufacturing concerns in Europe and America. It is unlikely that for a generation at least the Indian engineers will be able to establish sufficient self-supporting research to enable them to design and build plant of the largest sizes and equipped with the latest technical developments. The older firms may still be able, for a time, to maintain their lead and have something to offer to India which she herself cannot produce; but the writing is on the wall, for good or for ill.

On another aspect of the development of the power resources of the country, it is likely that Indian engineers will have something to learn from Western technique for very many years to come. This relates to the accurate forecasting of load and its incidence. This, in turn, has a profound bearing on the type of

plant designed for installation in a given location. The question of storage arises; the number of sets installed in a given location in the first and following stages of construction can only be economically planned if the ultimate utilisation is as clearly foreseen as other design details.

In heavily industrialised countries, load forecasting has been brought to a fine art. Local short-term forecasts, based on intimate knowledge of industrial, domestic, and population conditions in a given area, are supplemented by long-range forecasts based on wide statistical surveys, embracing the economics of industry, Governmental policy in regard to finance, defence requirements, the siting of industrial areas and their expansion or contraction, the transport network in relation to industry, trends in employment policy and conditions of work, additional usage of power appliances to aid manual labour, and many other considerations of this nature. Large organisations have been established for this purpose, and their basic data are obtained from many years of practice.

In India, as in other relatively undeveloped countries, the problem is totally different, and yet can be solved by the application of the same principles. A hydro-electric development may be remote from centres of population and may actually need industries to be specially established to make use of the available power until widespread rural and urban electrification commences to absorb the load. These "buffer" industries, as advocated by Monsieur Antoine of France, could be planned so that the whole equipment could be moved to a new site when its usefulness had expired on the first project.

While there is no doubt that there exists nowadays a body of engineering skill in India capable of the planning and designing of a given hydro-electric project, and possibly, if facilities were available, of the manufacture of all the components, it is unlikely that there would be found engineers who have worked for a sufficient length of time on the broader problems of power planning, including especially load forecasting, to ensure that the vast sums of money required for harnessing Indian water power could be wisely spent. It is here then that the guidance of Western engineers is perhaps most needed, and this is borne out by the intense interest shown in the papers at the Conferences which related to these matters.

Colorado River Developments

THE first of five 45,000 kW capacity generators in the Davis Dam power plant at Pyramid Canyon, 34 miles west of Kingman on the Colorado river between Arizona and Nevada, was brought into operation earlier this year. It is expected that at least one new generator will go into service every month until the plant is completed; then the estimated output of all five generators will be approximately a thousand million kilowatt-hours of energy a year.

Power produced at Davis Dam this year will be in time to aid the irrigation farmers in the south-west who in the past have suffered crop losses because of insufficient power for pumping. Acute shortages of power for irrigation work were also experienced in the Salt and Gila river valleys of Arizona, south-east of the project.

Davis Dam, the last of the Bureau of Reclamation (United States Department of the Interior) large dams to be built below Hoover Dam in the presently planned development of the Colorado River, uses the last major fall in this section of the river. It is the final step in the stairway of river dams on the lower Colorado stretching from Laguna Dam, 13 miles north-east of Yuma, Arizona, to Hoover, over 300 miles upstream. Other constructions include the Parker and Imperial Dams and the All-American Canal. An undeveloped low fall still exists at Pilot Knob which will be utilised when surplus water from the canal is used.

With the start of power generation at the Davis plant, the project will be fulfilling the multiple purposes for which it was built, namely (1) to serve treaty provisions pertaining to the division of Colorado river waters between the U.S. and Mexico; (2) to produce much-needed electricity; and (3) to re-regulate irregular water releases from Lake Mead through the Hoover power plant for the benefit of farmlands. The treaty with Mexico required that a dam be built in order to distribute a regulated delivery of 1,500,000 acre-feet of water annually apportioned to that country under the terms of the treaty.

But the development of the Colorado river does not end with the completion of the Davis Dam. There are many other fine spots on the main stem and branches of the river above Hoover where other dams could be built, notably in the Bridge, Glen and Marble canyons. Such dams would further regulate and conserve the river's water and energy, and their power plants, it is estimated, could double the present output of hydro-electric energy on the lower Colorado.

Hungry Horse Dam

BECAUSE of its importance as one of the major power and flood control projects in the U.S. Bureau of Reclamation's region-wide programme for the multiple-purpose development of water resources in the Columbia river basin, Hungry Horse Dam has been given construction priority. During 1950 over a million cubic yards of concrete were poured at the site and the schedule for this year includes the placement of an additional 1,200,000 cubic yards of concrete; a start will also be made with the installation of the first two 105,000 horse-power turbines.

Under the present construction schedule, one million acre-feet of water will be stored behind Hungry Horse Dam during the 1952 spring run-off. With the first two generators planned to go into service in October and December of next year, the water storage will make it possible for the Hungry Horse power plant to produce approximately 90,000 kilowatts of power to help alleviate power shortage conditions in the Pacific north-west during the 1952-53 winter peak-load period. This storage will also help power generation during the winter peak at downstream plants in Montana and on the Columbia river.

S.E. Asia Plan Finance

BURMA and Indonesia, two of the countries concerned in the South-East Asia plan for economic reconstruction, are among the latest to apply for membership of the International Bank for Reconstruction and Development, and final action on their cases has probably by this time been taken by the

Board of Governors. Pakistan, another South-East Asia Plan country, has authorised the use of four million rupees of its capital subscription to the bank. These capital payments are divided into three parts. Two per cent. of the sum is payable in U.S. dollars or gold, which can be used freely by the bank. Eighteen per cent., contributed in the currency of the member State, cannot be lent without the member's permission. The remaining 80 per cent. is not paid into the bank, but is subject to call if it is needed to meet the bank's obligations on borrowings and guarantees. Net income of the bank for the second half of 1950 was placed to General Reserve against losses on loans and guarantees, and the reserve now totals over 34½ million dollars.

Colombo Plan Loans

WORLD BANK loans are possible within limits for the Colombo Plan for the development of the countries of South-East Asia. The International Bank, it is announced from Washington, is prepared to give sympathetic consideration to any loan requested by countries taking part in the plan, and as an indication its practical interest the bank was represented at a recent meeting of the Consultative Committee of the Colombo Plan in Ceylon. It has been estimated that the Commonwealth countries themselves can advance about £1,030 million, leaving about £837 million to be raised abroad to meet the total sterling expenditure of approximately £1,867 million. The Bank is said to be willing to consider supplying part of the funds on a project by project basis, though it cannot hope to fill the gap completely.

India's Industries

INDIA'S short-term development plans are expected to be brought to their final stage this month. Originally they covered a period of five years ending 1955-56, but the Prime Minister (Mr. Nehru) has now announced that it is proposed to extend them to a sixth year in order to correspond with the period of the Colombo Plan. Schemes have already been received from most of the State Governments and Central Ministries and these are under examination by the Planning Commission. The Commission also will prepare an integrated programme of public undertakings and suggest detailed priorities. As regards private undertakings, the Commission has drawn up development plans in consultation with individual industries.

Science to aid Africa

THE importance attached to the development of south and central Africa is seen in the recent deliberations of the scientists of six countries in Nairobi. This body, the Scientific Council for Africa South of the Sahara, is representative of all states having special interest in the regions covered—the Union of South Africa, the United Kingdom and Colonies, Southern Rhodesia, France, Belgium and Portugal. The council's function, among other things, will be to make suggestions for greater liaison between the governments in lines of research, and the holding of special conferences for general advancement of the interests of Africa. Thus their work will be in a large measure complementary to that associated with the hydro-electric developments on the Upper Nile, outlined in earlier issues of WATER POWER. Sir Alexander Carr-Saunders, director of the London School of Economics and chairman of the Colonial Social Science Research Council, will represent the United Kingdom on the council, secretary-general of which is Dr. E. B. Worthington, Scientific Secretary to the High Commissioner for East Africa.

Italians for Australia

THE Australian Government has accepted an Italian tender for building most of the administrative buildings at Cooma, New South Wales, for the Snowy River hydro-electric scheme, now entering upon its first stages of development. The Minister for National Development (Mr. R. G. Casey) announced in Canberra that an undertaking by an Italian firm to finish this work within twelve months would mean the early transfer of the Snowy Mountains Authority from its present home in Sydney to Cooma, and completion of the work would be another step towards getting the first block of power in the scheme itself. He is hopeful that, with the present rapid rate of expansion, equipment developing 80,000 h.p. would become available in about four years.

Festival Features

HYDRO-ELECTRIC schemes will be represented among the many displays going to make up the Exhibition of Industrial Power to be held in Kelvin Hall, Glasgow, in conjunction with the Festival of Britain, which opens in May. The North of Scotland Hydro-Electric scheme, for example, will find a prominent place, while from oversea the great Nile Valley scheme, the aim of which is the improvement of the standard of living for millions of people, will be the subject of a special display. The exhibition as a whole is being designed to demonstrate outstanding British achievements in heavy engineering and its associated technologies. Responsible for its organisation is Mr. Alastair Borthwick, of the festival's science directorate, and the chief architect and designer is Mr. Basil Spence. The exhibition will be in narrative form, with exhibits arranged round a central story of British contributions to the conquest of power.

Power with a Purpose

THIS story will disclose how, by British enterprise, the once latent power of some of our mines and rivers has been harnessed to serve the daily needs of the people. It develops quite naturally, therefore, through two main sequences, one starting from coal, the other from water. The "Power of Water" sequence will include hydro-electricity, civil engineering and irrigation, and the "Power of Coal" will cover mining, iron and steel, various power units, and the generation and transmission of electric power. A final section will deal with nuclear energy. It is emphasised that the Exhibition of Industrial Power is in no sense a trade fair. The displays will be arranged as appropriate to the story to be unfolded, and no space will be rented by private firms or made available to any organisation as such.

A *glimpse of the Pangani Falls*

The Pangani Scheme

In common with most countries Tanganyika is faced with a growing demand for power and this article describes recent additions which have been made to the Pangani Station.

AN important East African hydro-electric generation and transmission scheme centred on the Pangani Falls in Tanganyika has recently been extended, and now supplies a much needed power increment to the important sisal plantations in the valley of the Pangani river. The preliminary plans, based on a survey carried out by the Power Securities Corporation Ltd., were first submitted to the Tanganyika Government for approval in 1930, and by 1936, the Tanganyika Electric Supply Co. Limited had completed the first stage of the project. A hydro-electric power station was built below the Pangani Falls (Fig. 2), and an extensive distribution network completed, the alternators and much of the switch-gear having been manufactured and installed by The General Electric Co. Limited of England. The additional generating plant which has recently been commissioned brings the total capacity of the station up to 12,500 kW and a further 5,000 kW alternator is now on order.

As will be seen in Fig. 1, the River Pangani rises on Mount Kilimanjaro, 19,320 ft. high, whence it descends to a plateau approximately 1,000 ft. above sea level. On its way the river passes through a considerable area of swampy ground from which rapid evaporation takes place in the tropical heat. Owing to the nature of its source and its passage through marshy areas, the river does not experience the great

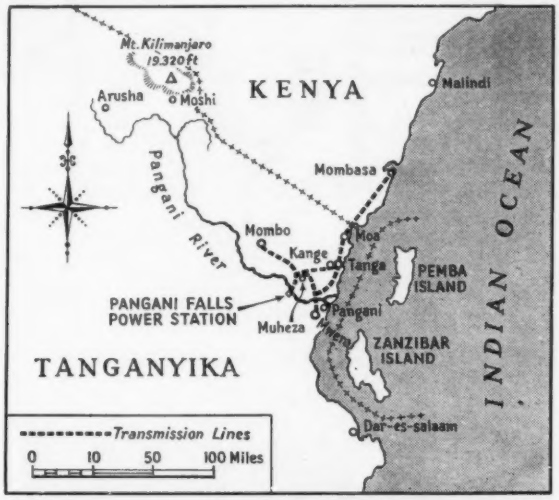


Fig. 1 (right). Map of Pangani River showing location of power station

Fig. 2 (below). View of power station from river

fluctuations in volume which are encountered in most rivers in tropical countries.

The main falls occur about 45 miles inland from Tanga; their total drop, which is about 400 ft., takes place in a series of rapids and falls embraced in a distance of about two-thirds of a mile, none of the individual falls being of any great height.

The power station is situated below the falls in a part of the country which is difficult of access. The Tanga-Moshi railway passes within about 10 miles of the site, and from the railway, a rough jungle road leads to one bank of the Pangani River. The power station, however, had to be built on the opposite bank and, until the new bridge was opened in January 1946, all material had to be transported across the river on a barge or pontoon.

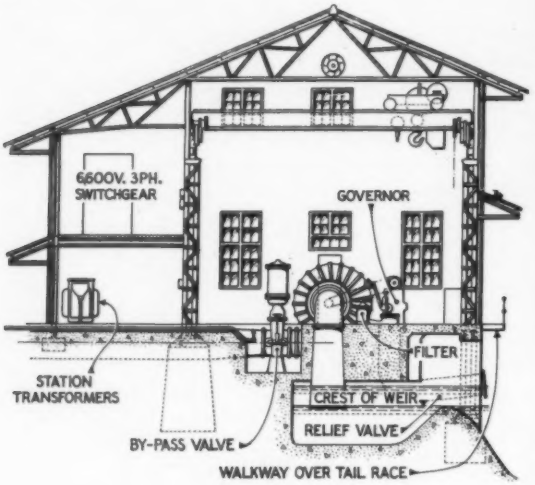


Fig. 3. Section through power station

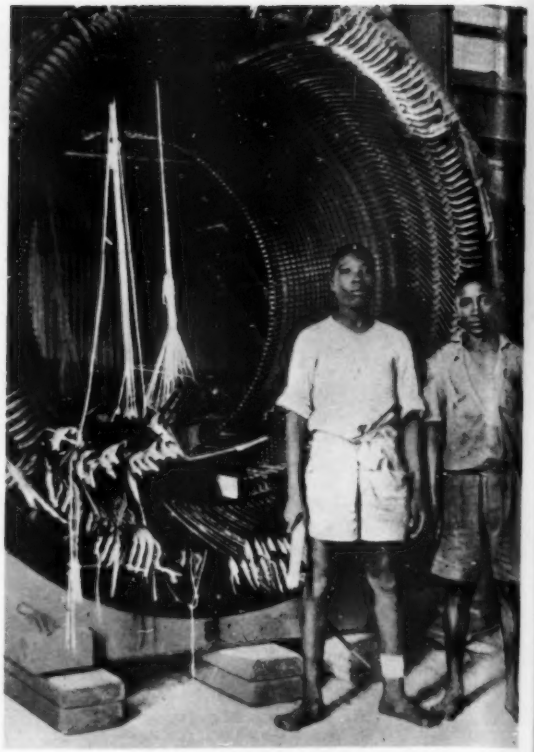


Fig. 5. Native workers refitting the stator coils of the 5,000 kW alternator

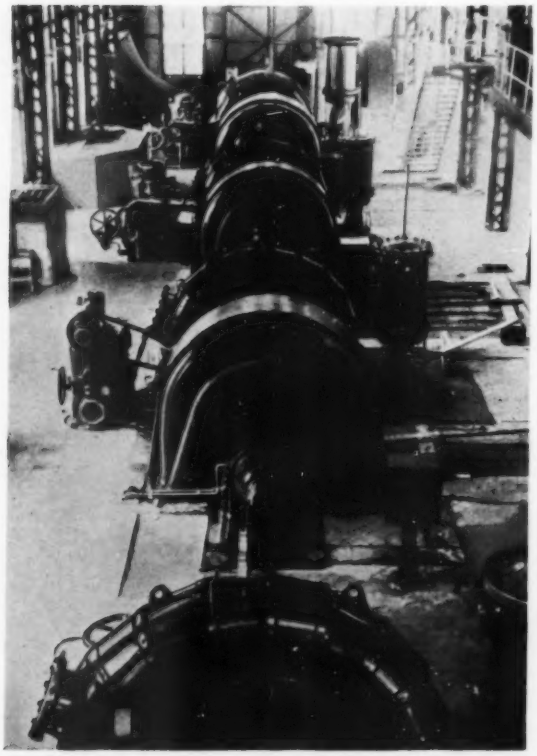


Fig. 4. Interior view of generating room

Intake Works

A channel of the river to the east of the falls furnished a suitable position for the intake works, and a twin pipe line, 1,240 ft. long, leading from this point to the power station below gives a head of 313 ft. For the first 418 ft. the pipes are 6½ ft. in diameter, after which they are reduced to 6 ft., the object of this grading being to reduce hydraulic friction in the upper section.

The intake dam is 290 ft. long and is constructed of concrete. The intake to the pipe line comprises a mass concrete structure in which are set six scour sluice gates to remove any debris which may accumulate. In the initial stage, only one pipe line was installed but provision was made for the second which was completed in 1949.

Power House

The power house itself, Figs. 2 and 4, is a steel framed building covered with asbestos-cement and galvanised-iron sheeting. The plant at present installed consists of four 6,600 volt, three-phase, 50 cycle,

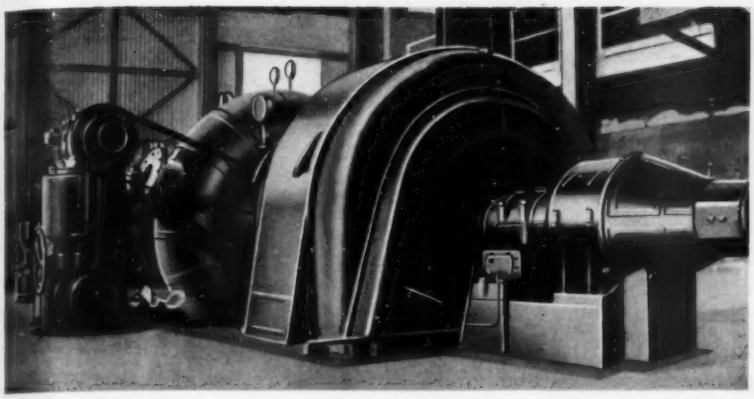


Fig. 6. One of the 2,500 kW, 750 r.p.m., 6,600 V, G.E.C. alternator sets

G.E.C. alternators, three of which are rated at 2,500 kW and one at 5,000 kW, each provided with a main exciter and pilot exciter. A view in the generating room is given in Fig. 7. These machines are driven at 750 r.p.m. by Francis horizontal shaft turbines built by Boving & Co. Limited, the smaller units being of the single-runner type rated at 3,600 h.p., while the larger is a double-runner machine rated at 7,200 h.p.

In view of the relatively high speed of the generating sets, a special design of alternator was adopted in which each of the eight poles is dovetailed into the rotor forging and forced into position under hydraulic pressure. Since the maximum load that could be handled over the ten miles betwen the railway siding and the power station was 12 tons, the poles of the 5,000 kW alternator were removed from the rotor after the machine had been tested at the works and were despatched as separate loads. The poles were re-fitted to the rotor in the power station.

Also owing to the weight limitation, the stator of the 5,000 kW machine was manufactured in two halves, and after passing the works test, twenty coils were removed adjacent to each joint to enable the stator to be despatched as two loads. The coils were re-fitted on site, Fig. 5.

On each of the 2,500 kW machines, Figs. 6 and 7, the two pedestal bearings are water-cooled, the turbine runner being mounted on an overhung portion of the alternator shaft. At this end of the alternator, a Michell bearing is used to take the thrust. At the other end of the alternator is the main exciter. The pilot exciter is mounted on a shaft extension overhung from the main exciter.

The rotor of the 5,000 kW alternator runs in its own water-cooled pedestal bearings and is solidly coupled to the flywheel and to the turbine shaft, also running in two water-cooled pedestal bearings, one of which is of the Michell thrust type.

Propeller fans are incorporated to give axial ventilation for cooling the alternators. The cooling air is taken from outside the building during dry weather and from inside the building when the weather is wet, and is discharged through ducts in the concrete below the machines.

The output of the four alternators is controlled by a 6,600 V cubicle-type switchboard installed in the gallery. This board also controls the three outgoing

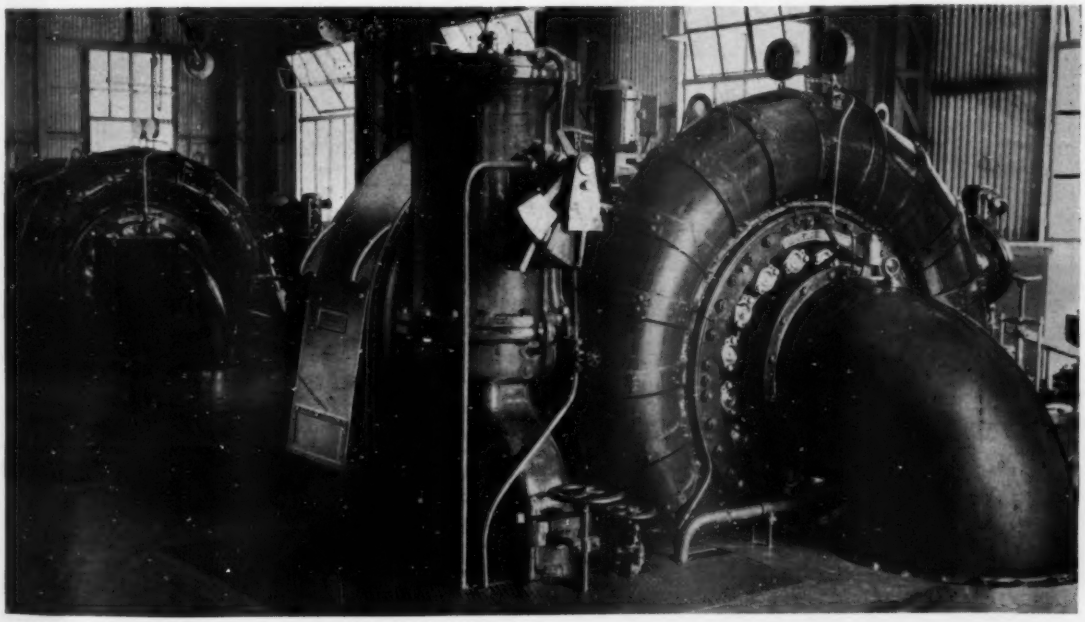


Fig. 7. Boving turbines direct coupled to 2,500 kW, G.E.C. alternators

feeders to the transformers which step up the voltage to 33 kV for transmission by an overhead system. Each circuit is equipped with an oil circuit breaker, the board being provided with duplicate busbars and two sets of busbar isolators on all circuits so that the circuit breakers may be connected to either set of busbars. In the centre of the board is a bus coupler panel arranged to couple the busbars together through an oil circuit breaker and isolators, thus enabling " on-load " changeover to be carried out between busbars. Mounted on the left-hand end of the board is a swing panel carrying the synchroscope, synchronising voltmeters and frequency meter.

Each alternator panel is equipped with an indicating watt-meter, ammeters, and a watt-hour meter, and with protective relays—the last mentioned including a triple-pole overload relay, a relay for the protection of the alternator windings and cables, and over-voltage and over-frequency relays.

As the gear is operated by Asiatic attendants, a most comprehensive system of interlocks is provided which not only prevents access being obtained to the interior of the cubicles until all associated apparatus is dead, but also prevents incorrect switching during synchronising and changing over from one set of busbars to another.

Each alternator is controlled from an exciter desk which is equipped with a direct-current ammeter and voltmeter, an automatic voltage regulator and hand regulators for the main and pilot exciters. A field discharge pillar is also installed.

Line voltage compounding equipment is provided, current transformers in each feeder cubicle being connected to a tapped transformer on which the desired tapping is selected by means of a master controller. The secondary of the tapped transformer is connected to the voltage regulator for each machine through a rheostat by means of which the degree of compounding applied to each alternator may be adjusted.

The feeder transformers are provided with 400 V tertiary windings, two of which are normally connected through isolating transformers to a flat-back distribution board which is arranged for three-phase, four-wire operation. This low tension supply is controlled by electrically operated oil circuit breakers. Triple pole overload and earth leakage protection is provided on the incoming panels of the board.

A number of two-wire and four-wire supplies are taken from this board and are controlled by switches and fuses. In addition, there are two rectifier panels, a battery panel, and a direct-current feeder panel, the direct-current supplies being used for auxiliary purposes, such as for operating circuit breakers.

Distribution Scheme

The principal power demand comes from the sisal factories which are scattered throughout the area, the growth and decortication of sisal for twine and cordage being Tanganyika's most important industry. The port of Tanga is also an important consumer, and recently, Mombasa township and the adjoining harbour at Kilindini have been connected to the Pangani station by an overhead line carried through some ninety miles of difficult bush country from the substation near Tanga.

A 33 kV ring-main distribution system was selected as the most suitable means of supplying the area to the north and east of the falls, where the greatest concentration of sisal plantations occurs. Each plantation has its factory equipped with decorticators, pumps, brushing and baling machines, requiring from 120 to 250 h.p. to drive them. Step-down transformers are installed at various points to supply 11 kV feeders and further ring mains. From this 11 kV system, local distribution is effected on a 400/230 volts, three-phase, four-wire system.

It should be mentioned that the denseness of the jungle, the absence of good roads, the resulting difficulty of transport—particularly during the heavy rains—and the unhealthy climate, all combined to make the construction of the overhead lines a matter of exceptional difficulty. Clearings had to be cut through the forest, not only for the transmission line right-of-way, but also to provide means of access for the constructional materials. The reinforced concrete poles, which are 36 ft. in overall length and each of which weighs nearly a ton, presented a particularly difficult transport problem.

This exacting task was successfully carried out by Balfour Beatty & Co., Limited, who were responsible for the whole of the design of the scheme and for its construction in a locality which is peculiarly remote from any engineering facilities. Acknowledgements are also due to " Civil Engineering " (No. 361, Vol. XXXI) for some of the information contained in this article.

From Our Parliamentary Correspondent

THE Scottish Office, in a White Paper, give details of Constructional Scheme No. 57, the Tobermory project, developed by the North of Scotland Hydro-Electric Board under the Hydro-Electric Development (Scotland) Act, 1943.

The White Paper states that this constructional scheme provides for an extension of the small existing hydro-electric scheme on the Tobermory River and for the installation of hydro-electric plant and diesel plant with a combined capacity of 1,000 kW at a generating station to be established in an existing building once used as the Ledaig Distillery, Tobermory.

A further constructional scheme, No. 51, refers to the Fasnakyle—Fort Augustus transmission line. This scheme provides for the erection in the County of Inverness of overhead transmission lines with one line of towers from Fasnakyle Transforming Station in the parish of Kilmorack to a new transforming station to be erected near Fort Augustus.

In the House of Commons on February 12th Mr. Morley asked the Minister of Fuel and Power what progress was being made in generating electricity from the water power of rivers and tides.

Mr. Robens, the Parliamentary Secretary, who replied, said that about fifteen hundred million units of electricity were produced in Great Britain from water-power in 1950; that was an increase of 25 per cent. on 1949. The greater part of this output came from the hydro-electric stations in Scotland and North Wales. It was often alleged that our river power could be used without the construction of large works; when such plans had been examined by his Department, they have been found to be impracticable. He added that the policy was to use water-power to the greatest possible extent.

Australian Developments

An Australian Correspondent gives brief particulars of the plants already in operation and outlines the scope of some of the large schemes that are either under construction or projected.

Les caractéristiques des installations hydro-électriques qui fonctionnent déjà en Australie sont brièvement données çi-dessous; l'article souligne d'autre part la portée de certains des grands travaux actuellement entrepris ou projetés. La capacité des usines hydro-électriques à la fin de 1949 était, déclare l'auteur, de 373 000 hp., soit 14% de la capacité totale des stations génératrices du Dominion. Les nouvelles installations étudiées ici devraient accroitre cette capacité de 500 000 hp. à la fin de 1957.

En este artículo se facilitan breves detalles de los proyectos hidroeléctricos que ya han sido puestos a la práctica en Australia y también comprende una descripción general de los desarrollos de importancia en proyecto o en curso de construcción. Se lleva indicado que la capacidad instalada de las centrales hidroeléctricas a fines de 1949 ascendía a 373.000 H.P., representando el 14 por ciento de la capacidad total instalada en todas las centrales generadoras de fuerza motriz de aquel Dominio Británico. Con las nuevas instalaciones hidroeléctricas que se discuten aquí, a fines de 1957 va a disponerse de una capacidad adicional de 500.000 H.P.

INSTALLED capacity of the hydro-electric power plants in Australia at the end of 1949 amounted to 373,000 h.p., representing 14 p.c. of the total installed capacity in all power stations throughout the Dominion. The subdivision of this total among four of the six States is as under:—

	h.p.
Tasmania - - -	247,500
Victoria - - -	70,000
New South Wales -	49,500
Queensland - -	6,000

It will be noticed that there are no hydro-electric power plants in South Australia or Western Australia. These two States have low rainfall and no large rivers capable of providing sufficient storages for continuous power generation.

Many new hydro-electric power plants are to be erected over the next seven years. The total additional capacity by 1957 is expected to be 500,000 h.p. of which 263,000 h.p. will be in Victoria and 187,000 h.p. in Tasmania. That is, at the end of 1957 the total installed capacity is expected to be 873,000 h.p.:—

	h.p.
Tasmania - - -	434,500
Victoria - - -	333,000
New South Wales -	49,500
Queensland - -	56,000

In addition to the approved schemes of which construction is certain, there are several large projects which are not likely to be completed for at least another ten years. These long-range projects include the huge Snowy River scheme in southern New South Wales, the Hume and Clarence River schemes also in New South Wales, and the Burdekin River scheme in central Queensland. The total capacity of these projected schemes is about 4,000,000 h.p.

A survey of present installations and future developments is given below:—

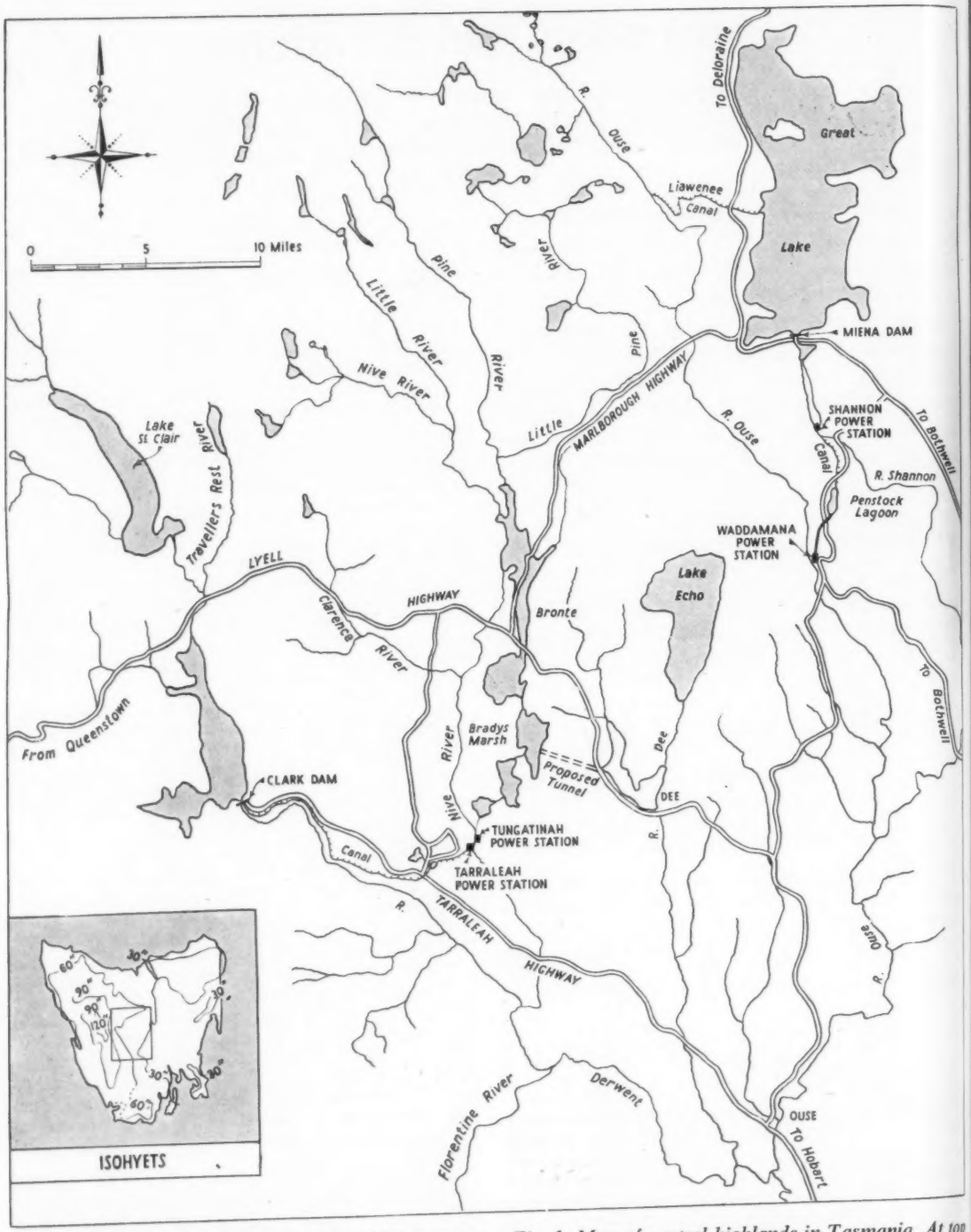
Tasmania

Water power development in Tasmania dates from 1895 when a small station of 75 h.p. was installed on the River Esk near Launceston. This development was the first in Australia. In later years the station was extended by the Launceston City Council, and in 1944 when the undertaking was absorbed by the Hydro-Electric Commission it had an installed capacity of 3,500 h.p. This plant is now maintained principally as a standby.

In 1911 the Hydro-Electric Power and Metallurgical Co. inaugurated the Waddamana scheme at the Great Lake. This site is at a high elevation near the centre of the island. In October, 1914, the company was purchased by the Tasmanian Government and placed under the direction of the Hydro-Electric Department, which was formed to develop these works, and to distribute the electric power to industrial centres. Under this Department the capacity of the Waddamana scheme was increased to 66,000 h.p. In 1930 the State hydro-electric works and the business of the Hydro-Electric Department were vested in the Hydro-Electric Commission of Tasmania.

Waddamana Scheme.—The original installation at Waddamana consisted of two 5,000 h.p. turbo-alternators supplied with water from a small dam at the outlet of the Great Lake, the natural level of which is 3,343 ft. above sea level. Enlargement of the station to a capacity of 66,000 h.p. was undertaken in 1919 when construction of a multiple arch dam was commenced at Miena at the southern end of the lake, where the natural outflow forms the River Shannon.

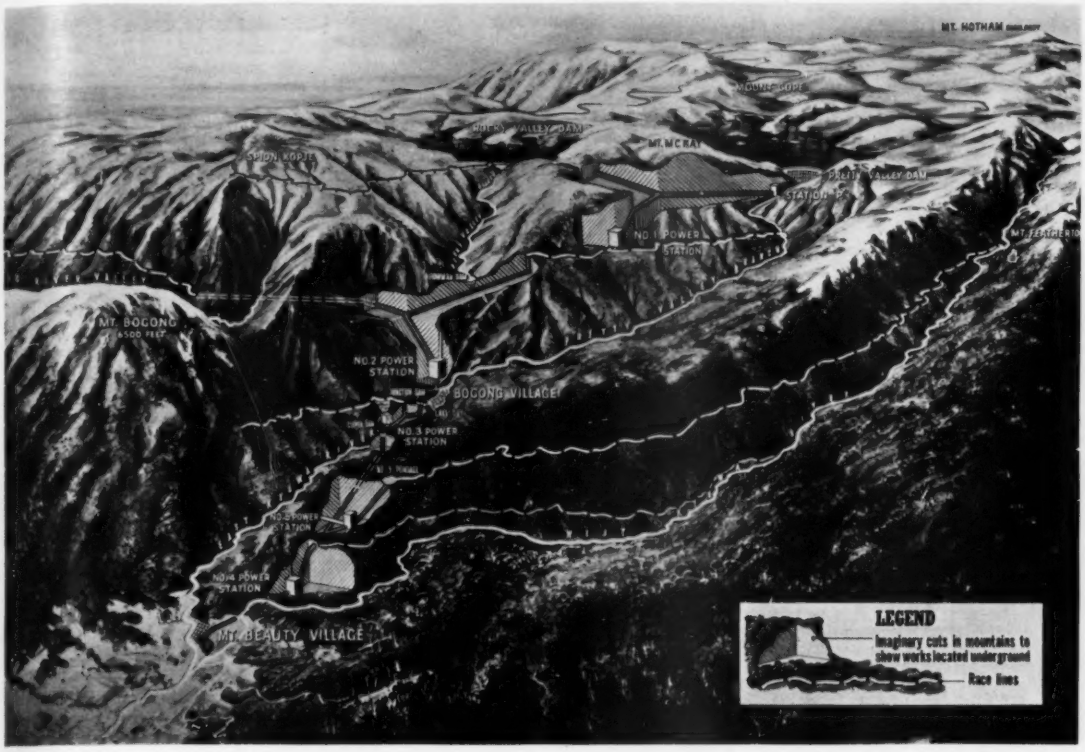
To utilise the water between this dam and the Waddamana canal, an earthen dam was built in 1934 to divert water from the Shannon River into a canal and thence through pipelines to the Shannon power station, 258 ft. below. This development added two 7,250 h.p. units to the system. The water having passed through this station discharges directly into the Waddamana canal. After passing through the Waddamana turbines the water discharges into the River Ouse. The storage capacity of the Great Lake is now 1,150,000 ac. ft. and the maximum static head at Waddamana is 1,127 ft. In 1944 after the establish-



ment of the Tarraleah power station (which operates as a base load station) it was decided to build a second station at Waddamana as a further source for peak load power. This station, which is known as Waddamana B, consists of four 15,000 kVA, 11,000 V English Electric alternators driven at 500 r.p.m. by 16,700 h.p. English Electric impulse type water turbines.

Tarraleah Scheme.—Water for the Tarraleah power

Fig. 1: Map of central highlands in Tasmania. At top right is the Waddamana hydro-electric scheme with Miena dam on the Great Lake, and Shannon and Waddamana power stations. At left is the Tarraleah scheme with Lake St. Clair, Clark dam and Tarraleah power station. In the centre is shown the proposed Nive River scheme with a power station at Tungatinah



station is provided by the Derwent River which flows in a southerly direction about 30 miles west of Waddamana. Storage is provided by Lake St. Clair and an artificial reservoir formed by the Clark Dam. Water is fed by flume and pipeline to a power station on the Nive River (see Fig. 1). This station was placed in service in 1938 with an initial installation of three 18,750 kVA Brown Boveri alternators driven by Boving Pelton wheels at 428 r.p.m. Two 18,750 kVA English Electric turbo-alternators were added in 1942 and a further unit of this capacity is on order. A pumped pondage is now completed and increases high load capacity during reduced flow by 25,000 kW. At Butler's Gorge, a short distance above the intake to the Tarraleah canal, a single-arch concrete dam has been built to control the flow of the Derwent River. This structure, known as Clark Dam, is 200 ft. high and has a capacity of 243,200 ac. ft. A power station having an installed capacity of 14,000 h.p. will be constructed at the foot of the dam to use the energy of the water passing from the reservoir to the Derwent River.

Nive River Power Development.—New works now in the early phases of construction include the Nive River development which involves the storage of water from the Nive River and Lake Echo catchments, and its use in a power station on the Nive River immediately above Tarraleah. These two catchment areas combine to form the extensive plateau area between the Great Lake and Lake St. Clair catchments (see Fig. 1).

A mass concrete dam, 115 ft. high, will be built near the junction of the Nive and Pine Rivers and this structure will store water and divert it to a series

Fig. 2: Layout of Kiewa hydro-electric project of the Victorian State Electricity Commission. There will be six power stations all of which will be underground except No. 3. Total capacity will be 289,000 kW and total net head 4,200 ft. Main water storage will be in the Pretty Valley and Rocky Valley reservoirs on the Bogong High Plains. The water will pass through stations Nos. 1, 2, 3 and 4 in succession and will then lead into a large pondage on the Tawonga Flats for regulating the discharge into the Kiewa river. The flow will be supplemented by water from Big river which will be fed by tunnel to a point just above No. 2 power station, and water from the West Kiewa river which will feed No. 5 power station and which will enter the main system at a point just above No. 4 power station. Station P at Pretty Valley dam will have reversible turbines for pumping water or generating electricity as required

of marshes that will form a chain of lakes extending in a southerly direction. Levees will be built across the outlets of these lakes. The water will pass from the lakes through steel pipelines to the forebay above Tungatinah power station.

The waters of Lake Echo and the Dee River will be diverted into this system by a dam on the Dee River and a tunnel between the dam and Brady's marsh.

Ultimately the capacity of the Tungatinah development may reach 150,000 h.p.

Generating plant for Tungatinah comprises four 35,000 h.p. Boving water turbines each driving a 31,250 kVA General Electric Co. (England) alternator. Delivery of the first units of this plant is due in 1952.

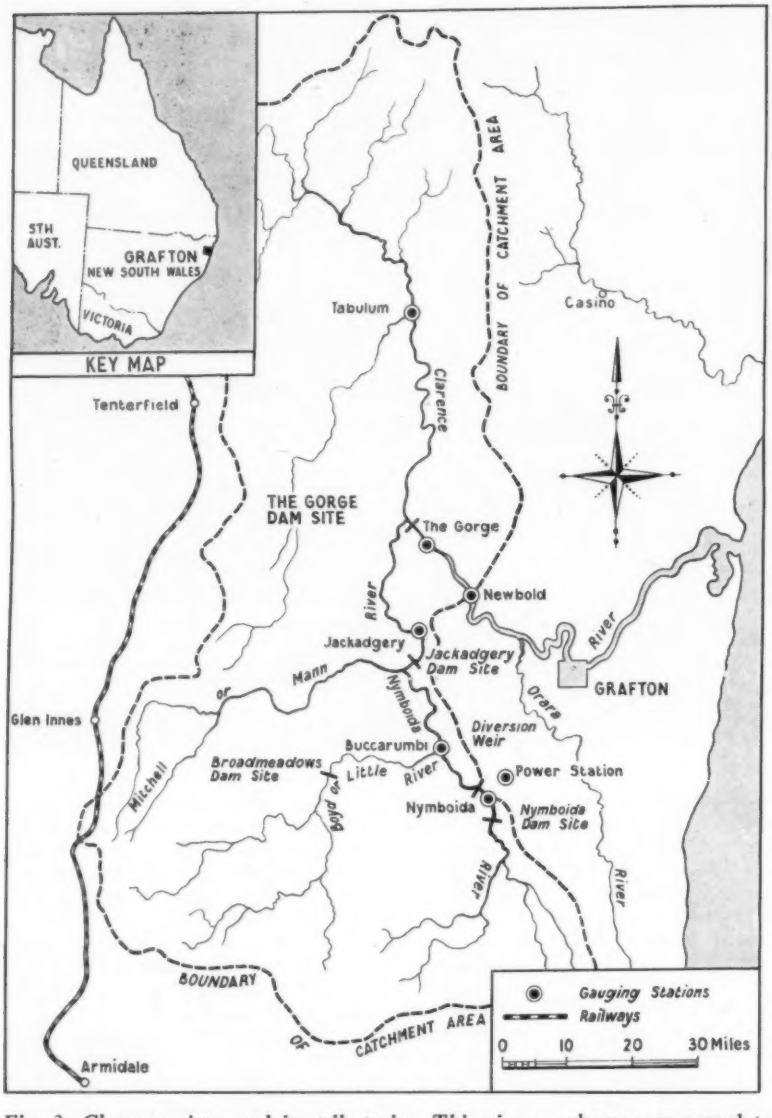


Fig. 3: Clarence river and its tributaries. This river system, which is in a rich agricultural area in Northern New South Wales, is being surveyed as a source of hydro-electric power. Preliminary estimates indicate that the economic potential may be between 300,000 and 400,000 kW. The map also shows the location of the Nymboida dam and power station, an existing undertaking of 4,800 kW controlled by the Clarence River County Council

Trevallyn Power Development.—To provide power for the aluminium works at Bell Bay of the Australian Aluminium Production Commission, the Hydro-Electric Commission will build a station at Trevallyn. The work will involve the construction of a power station at sea level and works to bring water from the South Esk River to the Tamar River about two miles from Launceston. The capacity of the station will be approximately 60,000 kW. Generating plant has been ordered but is not expceted to be available until after 1953.

Lake Margaret Scheme.—The Lake Margaret station is operated by the Mount Lyell Mining and Railway Co. to meet the requirements of their copper mining activities on the West Coast. It consists of two stations, the upper having six Boving and one Gilkes Pelton wheels each coupled to an alternator of 1,200 kW capacity. The lower station has one Boving Francis turbine coupled to a generator of 1,500 kW capacity. The Company's transmission system is linked with the West Coast transmission system of the Hydro-Electric Commission.

Victoria

The north-eastern area of Victoria provides the conditions most favourable to water power development. The Great Dividing range with an elevation of 4,000 to 5,000 ft. above sea level and extensive plateaux is subject to an average precipitation of well over 60 in. per annum, much of this being in the form of snow. The natural storage in the snow cover results in a greater and more regular run-off and amongst the most promising developments are those of the Kiewa, Murray and Mitta Mitta rivers.

Existing hydro-electric installations in Victoria prior to the first of the Kiewa stations were centred around the Sugarloaf Rubicon area. A total of 36,800 h.p. is developed in five stations. This scheme was completed in 1928.

Kiewa Hydro-Electric Project.—By far the major water-power scheme being developed in Victoria is that using the headwaters of the East and West Kiewa rivers. The layout of this scheme is shown in Fig. 2.

Kiewa will have seven reservoirs to store and utilise water from a total catchment area of 175 square miles. Of the two main storages, the larger will be at Pretty Valley which will have a full supply capacity of 160,000 ac. ft. at an elevation of 5,590 ft. Five miles away and 150 ft. lower, a dam at Rocky Valley will store 22,000 ac. ft. Half of Pretty Valley storage will be held as reserve to be used only in drought periods.

These two storages will draw water from 47 square miles of country and each will gather the run-off from its own catchment. Rocky Valley dam will also receive water diverted by race lines from an additional 32 square miles of the High Plains and Big River catchments. It will be possible, when Rocky Valley is filled to capacity, to pump from there to Pretty Valley dam to avoid waste.

At successively lower elevations, four smaller pondages will provide a head of water above various power stations by storing the main water flow for their day to day operation. Several of these pondages will receive extra water diverted to them by race lines from creeks and springs in their adjacent catchment areas. One of these pondages, named Lake Guy, has already been formed by Junction Dam on the East Kiewa river. Water from this pondage is used to operate the existing power station of 26,000 kW capacity (No. 3).

At the foot of the ranges, and overlooked by Mt. Beauty village, a large artificial lake will receive all the water used in the scheme, discharged from the lowest power station (No. 4). This pondage will regulate the daily flow of water back into the West Kiewa River.

Dams and dykes.—Pretty Valley Dam will be a curved, reinforced-concrete, multiple-arch structure, and will be one of the largest of its type in the world. It will be nearly a quarter of a mile long, and 211 ft. high at its centre. Three subsidiary dykes of earth and rock construction will be used to close low saddles in the watershed.

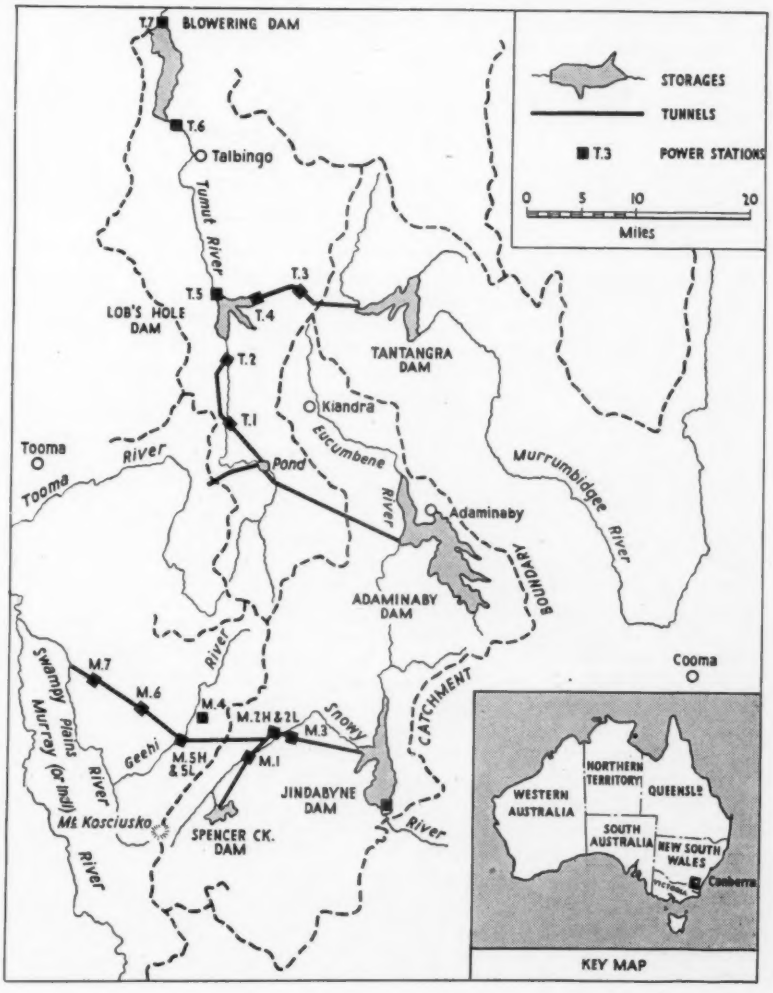
Rocky Valley reservoir will need only one dam. It will be 100 ft. high and a third of a mile long at its crest. A vertical shaft spillway, ending in a large diversion tunnel, will be designed to pass maximum flood water from the reservoir. Howman Dam and Clover Dam will be constructed to form pondages for No. 2 and No. 4 power stations respectively.

Water diversion races.—The collecting system, totalling about 150 miles, will have races varying in length from one to thirty-one miles, and in capacity from 3 cusecs to 700 cusecs. The three most important schemes will be that on the High Plains for diverting additional water into the Rocky Valley reservoir, that for gathering water from both sides of the Big River valley for diversion by tunnel into the main water flow above No. 2 power station, and the system on Mount Fainter in the West Kiewa valley for feeding the pondage for No. 5 power station.

A total of 18 miles of tunnels driven through solid rock under the mountains constitutes the major means of water flow from the storages to the power stations. The largest tunnel will be that from the tail race of the lowest power station (No. 4) which will discharge water at the maximum rate of nearly 34 million gallons per hour. For the most part tunnels will remain unlined except where concrete lining is necessitated by geological faults. Pressure tunnels will be lined with steel.

Underground power stations.—With the exception of No. 3 station, already built above ground, the five other stations will be located underground. The 17 turbo-generators which comprise the completed scheme will have a combined generating capacity of 289,000 kW. The largest station will be No. 2, with

Fig. 4 (below): Map of proposed Snowy Mountains irrigation and hydro-electric scheme. Two developments are involved: (1) The diversion of 565,000 ac. ft. of water from the Eucumbene and Tooma Rivers to the Tumut Valley and thence to the Murrumbidgee River, with main storages at Adaminaby, Lob's Hole, Tantangra and Blowering, and seven power stations T.1 to T.7, having a total installed capacity of 1,180,000 kW; (2) The diversion of 400,000 ac. ft. of water from the Snowy River to the Murray River with main storages at Spencer Creek and Jindabyne, and nine power stations (Nos. M.1, M.2H, and 2L, M.3, M.4, M.5H, and 5L, M.6 and M.7), having a total capacity of 1,680,000 kW



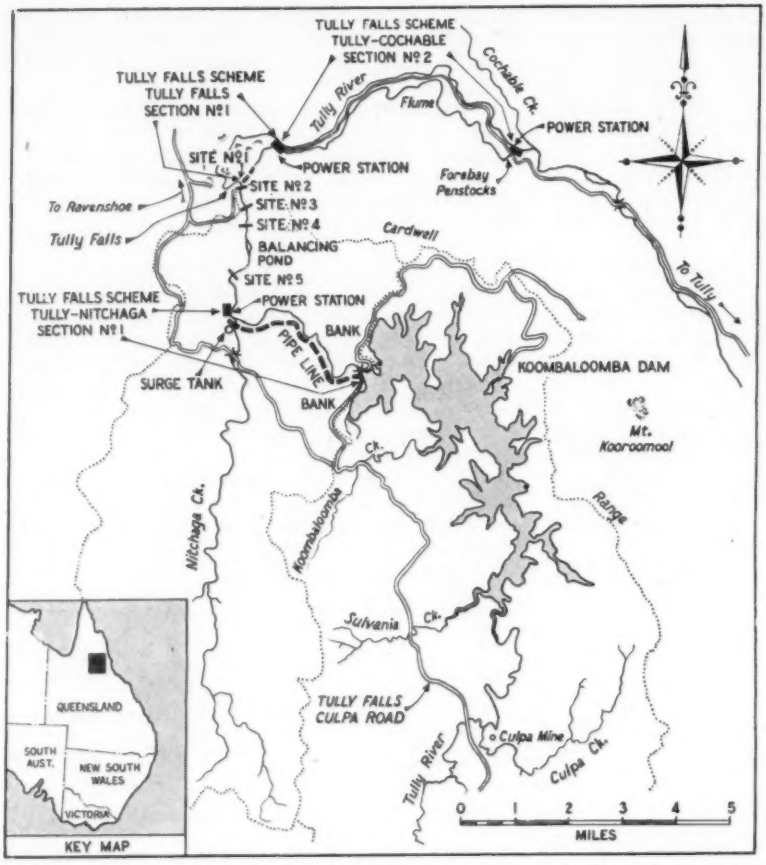


Fig. 5: Proposed hydro-electric development of the Tully River, North Queensland. The scheme will be developed in three sections. No. 1 with power station site near Tully Falls will have an installed capacity of 72,000 kW; No. 2 further downstream will have a capacity of 15,000 kW; and No. 3, above the falls, will have a capacity of 5,400 kW

four sets and a total capacity of 98,000 kW; it is scheduled for service in 1955. It will be 650 ft. below the surface and access will be gained by an electric lift operating in a vertical shaft. No. 4 station will be 450 ft. below surface level and will comprise four 15,000 kW machines, three to be installed in 1951 and the remaining one in 1953.

Deepest underground but with access by tunnel from the mountainside are No. 1 and No. 5 stations. No. 5 station, with two machines totalling 32,000 kW capacity, is scheduled to begin operating in 1953, whilst No. 1 station will bring three machines totalling 60,000 kW capacity into service in 1954-55.

The smallest of the six stations will be that designated "P," which will be just below Pretty Valley Dam. Its capacity will be 13,000 kW with two machines, able to generate electricity when water flows from Pretty Valley storage, or to pump water into that storage from Rocky Valley when required.

High-tension transmission.—Kiewa power will be transmitted to Melbourne over a double-circuit 220 kV steel-tower transmission line and the complete scheme, comprising 289,000 kW, is expected to be in operation by 1956. The total capital expenditure is expected to be approximately £25,000,000, and this scheme will be the largest hydro-electric development to date. It will meet about one-third of the anticipated demand on the Commission's system — estimated at 745,000 kW by 1956 —and will supply nearly the same proportion of total annual output of the system.

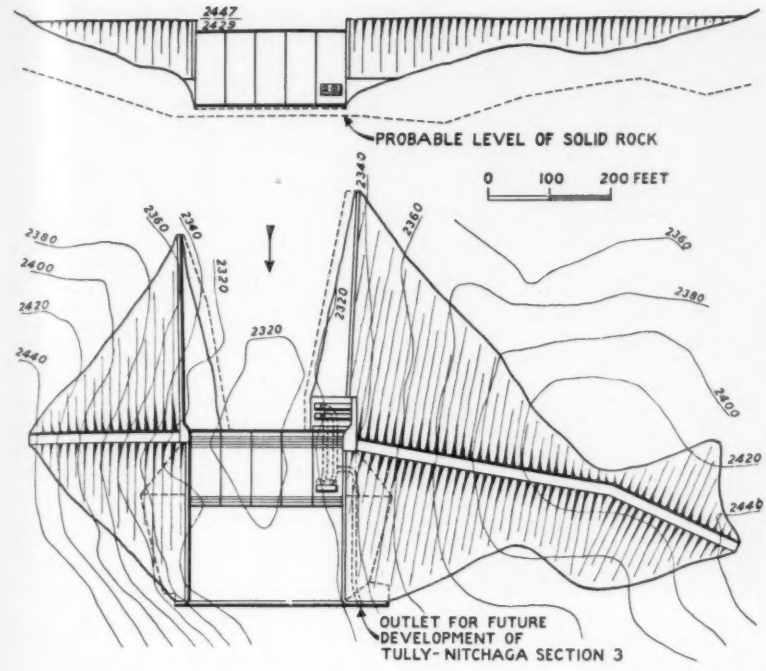
Eildon Reservoir.—A power station of approximately 120,000 kW will be installed at the new Eildon Reservoir planned by the Victorian State Rivers and Water Supply Commission. The existing reservoir, which has a storage capacity of 306,000 ac. ft., provides storage for irrigation in the Goulburn Valley. A power station with a capacity of 12,000 kW is in operation and supplies power to the Victorian network. The new structure, which will be of the earth and rockfill type, will be built immediately downstream of the existing embankment, and will provide a storage of 2,750,000 ac. ft. Tenders have been invited for the construction of the dam.

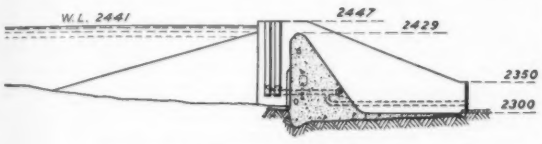
New South Wales

Hydro resources in this State exist mainly in the south and in the north-east. In the south there are two stations at the Burrinjuck dam which was built by the Department of Public Works primarily for irrigation purposes. Each station is equipped with two machines. The total installed capacity is 20,000 kW. At Wyangala on the Lachlan River near Cowra another dam has been built by the Irrigation and Water Conservation Commission, again for irrigation purposes. This station contains a single 7,500 kVA vertical-shaft turbo-alternator.

In the north of the State, the Clarence River County Council has installed a plant of 7,900 h.p. on the Nymboida River, a tributary of the Clarence. The plant here consists of five 800 kW and two 400 kW turbo-alternators.

Clarence Gorge Scheme.—The Electricity Authority of New South Wales has already carried out extensive investigations into the possible economic development of this area as a source of electric power and has reached a stage where a report on the hydro-electric potentialities can be expected shortly. Aerial and ground surveys have been completed and the work so far carried out indicates that the construction of a dam at the Gorge and the installation of hydro-electric plant will provide an economic source of power of over 75,000 kW. A study of the whole river system indicates that the total economic development may





SECTION THROUGH SPILLWAY

prove to be between 300,000 kW and 400,000 kW. By far the greater part of this total is contributed by the tributaries of the Clarence in the southern part of the catchment upstream from Nymboida. Development of this area is expected to provide about 150,000 kW capacity at a cost cheaper than thermal power. Investigations are continuing in regard to possible sites for other dams and stations. (See Fig. 3).

Hume Reservoir.—Recently approved plans for the enlargement of this reservoir from 1,250,000 ac. ft. to 2,000,000 ac. ft. include the installation of two 25,000 kW turbo-generators. The original design of the dam made accommodation for three discharge valves for hydraulic turbines. The turbo-generators will be of the vertical type with an output of 25,000 kW

Fig. 6 (above): Proposed Koombooloomba dam on Tully River; concrete spillway section will be 250 ft. long and 129 ft. high

Fig. 7 (below): Dragline working on preliminary race line excavation at No. 5 Workshop bench site of the Kiewa hydro-electric scheme

Fig. 8: Preparing the bench for cableway tower at Pretty Valley dam site Kiewa hydro-electric scheme. This tower will be one of two erected to carry the equipment for placing the concrete. The earthmoving units shown are Tournapulls and Carryalls

at 0.9 power factor lagging, with cooling water at 25°C. and 95 ft. head. Generation will be at 11 kV and the machines will be stopped and started in automatic sequence with manual synchronising.

Since the prime purpose of the reservoir is the provision of water for irrigation, electricity generated will be dependent on the amount of water released for irrigational purposes. As a result of this, there will be wide variations in both the flow and head available. To cope with these variations Kaplan type turbines are to be installed.

One generator will be connected through a 11/132 kV transformer to the network of the Southern Electricity Supply of New South Wales while the other will be connected through a 11/66 kV transformer to the Victorian State Electricity Commission's system. Facilities will be provided for interchange of power between the two systems and for parallel operation of the generators on either system. Provision has been made for the installation of a third set if required. Average output of electricity from the station is estimated to be in the neighbourhood of 200,000,000 kWh yearly.

The original reservoir, completed in 1936, comprises a mass concrete spillway 1,040 ft. in length, flanked on either side by earthen embankments with a reinforced concrete core wall. The increased dam capacity will be obtained by raising the water level from R.L. 606 ft. to R.L. 626 ft.; the additional work involved will consist of placing the last five feet of concrete on the spillway and installing 29 mechanically operated steel gates between existing piers. The structure contains seven needle valves, four used in regulating river flow and three for the turbines. The design of the power station is being carried out by the Victorian State Electricity Commission while the construction and responsibility for operation will be undertaken by the Public Works Department of New South Wales. Delivery of the machines is not anticipated before 1953.

Bega Valley Development. —Bega Valley County Council in South-Eastern New South Wales operates a small hydro-electric station. One 500 kW set is installed, and two 750 kW units are being installed.

Snowy River Development. —After very extensive investigation by a select committee of Commonwealth and State officers, agreement has been reached on a plan for utilising the waters of the Snowy River area in southern New South Wales. The final scheme, known as the Snowy-Murray-Tumut Development, envisages a maximum firm capacity of 2,860,000 kW at a capital cost, excluding transmission, of £125,000,000. The capital cost of the transmission system is estimated to amount to about £100,000,000. The relative economy of the scheme is evident from the fact that the saving in costs, compared with a modern steam plant, is estimated to be about £9,300,000 per annum, after allowing for the increased transmission costs for the Snowy scheme.

To safeguard irrigation interests and to ensure a proper sharing of the benefits of the scheme, a complete agreement has been made by the three Governments concerned. It is of interest to note that after the deduction of Commonwealth requirements, the power available from the Snowy Mountains project is to be shared by the two States in the proportions: New South Wales, two-thirds; and Victoria, one-third.

The complete scheme comprises two developments, firstly, the diversion of the flow of the Eucumbene River and the Tooma River to the Tumut River with compensating flow from the Snowy to the Murray River. This is known as the Tumut Valley Development. Secondly, there is the utilisation of the balance of the Snowy River waters by diversion from near Jindabyne to the Murray River.

Tumut Valley Scheme. — In the Tumut Valley development the waters of the Upper Eucumbene, which flow south to join the Snowy River near Jindabyne, will be diverted and some 235,000 ac. ft. discharged to the Upper Tumut (See Fig. 4). The Upper Tooma, a tributary of the Murray River, will divert about 334,000 ac. ft. of water to the Upper Tumut and in such a way tnat, when required, the flow of the Upper Tooma and the Upper Tumut can be turned back through the tunnel between the Eucumbene and Tumut Rivers to the storage dam at Adaminaby on the Eucumbene. This will provide regulation for the flow of these rivers; it will also add a considerable amount of water to the Murrumbidgee for irrigation and greatly assist in the otherwise difficult control of the Upper Tumut River.

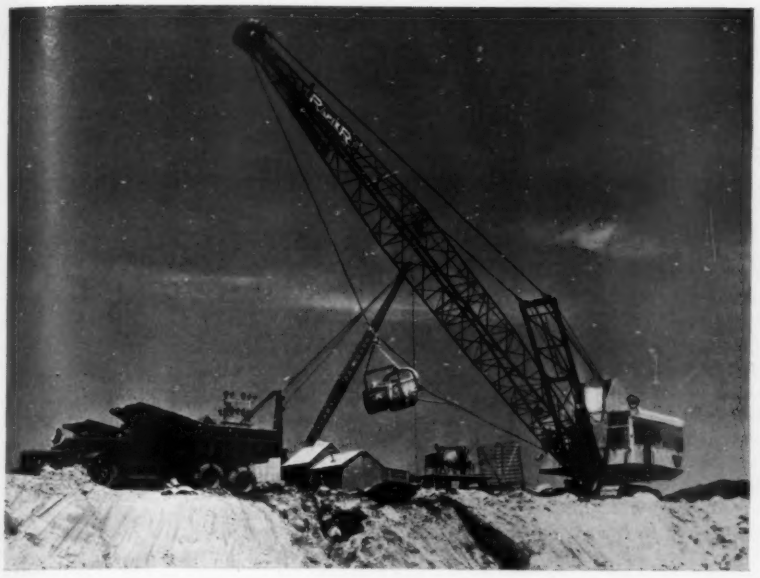


Fig. 9: "Rapier" excavator fitted as a dragline loading trucks at the Rocky Valley dam. This dam will be one of the main storages for the Kiewa hydro-electric scheme of the Victorian State Electricity Commission. The trucks shown in the photograph are "Diamond T" units fitted with specially designed bodies

Further developments include the diversion of the waters of the Upper Murrumbidgee from a dam near Tatangra to the Tumut Valley.

Construction Features.—Construction of the scheme will involve the following:—

(1) A dam on the Eucumbene near Adaminaby, capacity 1,000,000 ac. ft.
(2) A tunnel from the dam to Tumut, 14½ miles long and 22 ft. in diameter.
(3) A tunnel from the Tooma to the Tumut, 5¼ miles long and 22 ft. in diameter.
(4) Two tunnels down the Tumut, 11 miles in length, to power stations 1 and 2.
(5) A dam on the Upper Murrumbidgee near Tatangra having a capacity of 300,000 ac. ft.
(6) A tunnel from this dam to the Tumut catchment, 6¾ miles long and 16½ ft. in diameter, with No. 3 power station at the outlet.
(7) A tunnel in the Tumut catchment from No. 3 to No. 4 power stations, 4½ miles long.
(8) A dam on the Tumut at Lob's Hole, impounding about 100,000 ac. ft., connecting with power station No. 5.
(9) A raceline about 40 miles in length to power station No. 6, past Talbingo.
(10) A dam at Blowering on the Lower Tumut to regulate the flow required for irrigation.
(11) Racelines in the Upper catchments of the Murrumbidgee, Eucumbene, Tooma and Tumut rivers, totalling about 130 miles in length.
(12) Seven power stations: Nos. 1 and 2 in Upper Tumut, Nos. 3 and 4 in branch from Upper Murrumbidgee, No. 5 at Lob's Hole dam, No. 6 on the raceline past Talbingo and No. 7 at Blowering dam.

It is estimated that the average annual output of these stations will be 3,000,000,000 kWh, and that the annual saving of coal will amount to 1,710,000 tons.

Snowy-Murray Scheme.—As previously indicated in the Tumut Valley scheme, the Murray flow is reduced by 334,000 ac. ft. by the diversion of Tooma flow to Tumut River. In order to make up this reduction a storage of not less than 1,500,000 ac. ft. is to be provided on the Upper Murray and 730,000 ac. ft. of water is to be diverted from the Snowy at Jindabyne to the Murray (see Fig. 4). This increased storage in the Upper Murray will increase the regulation of the Murray so that a further 150,000 ac. ft. of water will be made available each year for irrigation. This brings the total for the two States to 225,000 ac. ft. per annum.

Features of Construction on the Snowy-Murray Section. — (1) A dam on the Snowy at Jindabyne, impounding approximately 1,100,000 ac. ft.

(2) A tunnel, 17½ miles long, from the Jindabyne storage to below the Geehi River.
(3) A pond on the Geehi, formed by a weir about 120 ft. high.
(4) A tunnel, 4½ miles long, from the Geehi to station No. 6, at Bogong Creek.
(5) A 6¾ mile tunnel from Bogong Creek to Station No. 7 and to Swampy Plains River.
(6) A dam at Spencer Creek, impounding approximately 15,000 ac. ft.
(7) Racelines feeding Spencer Creek storage (approximately 60 miles) and Finn's River pond, Station No. 2H (approximately 18 miles).
(8) Tunnels from Spencer Creek storage to Island Bend, supplying Stations 1 and 2, total length approximately 10 miles.
(9) Racelines feeding Island Bend; Jindabyne; Windy Creek pond; Stations 5H and 5L; and Station No. 6.
(10) Nine power stations having the following particulars:—Nos. 1 and 2L, on the Snowy using head between Spencer Creek and Island Bend (installed capacities of 92,000 kW and 42,000 kW respectively); No. 2H, using head from Finn's River Pond to Island Bend (installed capacity, 22,000 kW); No. 3, using head from Island Bend to Main Tunnel (installed capacity, 190,000 kW); No. 4, using head from Windy Creek Pond to Station 5H Pond (installed capacity, 47,000 kW); No. 5H, using head from 5H Pond to Geehi Pond (installed capacity, 66,000 kW); No. 5L, using head from Geehi Pond to Main Tunnel (installed capacity, 21,000 kW); No. 6, using head from Jindabyne (Main Tunnel) to Bogong Creek (installed capacity,

290,000 kW); No. 7, using head from Bogong Pond and Swampy Plains River (installed capacity, 910,000 kW).

(11) Dam on the Upper Murray catchment to regulate the flow to irrigation requirements (storage not less than 250,000 ac. ft.).

The total installed capacity of the Snowy-Murray diversion will be 1,680,000 kW involving the construction of three major dams, 39½ miles of tunnels, 330 miles of racelines and nine power stations. The complete Snowy - Murray - Tumut Development will involve the building of seven major dams, 86 miles of tunnels, 490 miles of racelines and 16 power stations with a total installed capacity of 2,860,000 kW.

No difficulty is anticipated in using effectively all the hydro-electric power that can be made available by the full development of this scheme. From the defence aspect the scheme offers well dispersed, effectively protected power stations, requiring the minimum of operating labour. Construction work on this scheme has commenced under the new Snowy River Hydro-Electric Authority set up for the design, construction and functioning of this scheme.

Queensland

Comparatively little development is likely in Queensland because of the topographical and climatic features. There are no snow-clad mountains and the river flow is dependent almost entirely upon rainfall. Only the Barron, Tully and Burdekin rivers have been considered as favourable for hydro-electric development.

Barron Falls Scheme.—At Barron Falls near Cairns the Cairns Regional Electricity Board has a station which was built during the years 1932 to 1935. The original installation comprised two 2,000 h.p. sets, situated underground and in 1939 a third generating set was installed. Further development on the Barron River is not contemplated.

Tully Falls Scheme.—To provide for increasing power demands in the Cairns Regional Area, the Board has, in association with other authorities, carried out investigations on the Tully River. As a result of this work the following scheme has been proposed. It is estimated to cost £11,560,000 and will involve the construction of three separate power stations in the following sequence:—

(a) Tully Falls station with four 18,000 kW sets operating on a gross head 1,485 ft.
(b) Tully Cochable station with two 7,500 kW sets operating on a gross head 405 ft.
(c) Tully Nitchaga station with one 5,400 kW set operating on a gross head 230 ft.

Full development of (a) will be carried out in four separate stages, while (b) and (c) will be carried out in one stage (Fig. 5). Approval has been given for the immediate construction of the first stage of the Tully Falls scheme. This will comprise a major dam 147 ft. high-diversion weir, intake works, tunnel, penstock, first section of power station building, two 18,000 kW generating sets and associated equipment, and 214 miles of 132 kV transmisssion line to distribute the energy to Mount Garnet, Atherton, Cairns and Innisfail. This section will provide an output of 130,000,000 kWh a year and involve an expenditure of £7,636,000.

Burdekin Development.—Construction of a hydro-electric power station of 42,000 kW minimum capacity at 50 p.c. load factor is included in a huge scheme of land development based on the Burdekin River in central Queensland. The estimated cost is £30,000,000, this including the cost of constructing a large dam 100 miles from the river mouth and the irrigation of 250,000 acres. Investigations into technical aspects are proceeding.

The various photographs reproduced in this article are published by courtesy of "The Age," Melbourne.

SCHEMES AND CONTRACTS

LOCH CALDER HYDRO-PUMPING SCHEME

Gilbert Gilkes & Gordon Limited, Kendal, will be acting as main contractors for the hydraulic power and pumping plant which will be installed at Hoy Filtration Station for the County of Caithness Loch Calder Hydro-Pumping Scheme. Although the amount of power generated will be relatively small, the technical features of the installation are of interest.

Two 58 b.h.p. spiral cased Francis turbines will drive centrifugal pumps which will deliver 880,000 gallons of filtered water a day to Stemster reservoir and two hydrostats will deliver 350,000 gallons per day to Ormlie Reservoir, Thurso. In addition, three Turgo Impulse Wheels with hand spear regulators and deflector governors, each coupled to a 12·5 kVA alternator, will provide lighting and electric power at the Filter Station. The above units include standby plant. The turbines will be supplied through a 24 in. diameter pipeline, 19,600 feet long, and special attention in the design of the plant has been paid to the development of power at the highest possible efficiency and the provision of control gear which will give accurate speed, flow and voltage control without setting up water hammer in this main. The total value of the contract is £21,400.

MUCOMIR CONSTRUCTIONAL SCHEME

The North of Scotland Hydro-Electric Board have published their Mucomir Project (Constructional Scheme No. 26) which will use water from Loch Lochy in Inverness-shire for the annual production of nine million units of electricity to augment supplies in Fort William and the surrounding district. The scheme is estimated to cost £295,000. It makes use of the flow of water through the Mucomir Cut, an artificial channel that is part of the Caledonian Canal works, after the needs of the Canal have been met. The water will be supplied to the power station by a short tunnel from the Mucomir Cut and will be discharged into the River Spean. There will be one turbo-alternator with a capacity of 1,500 kilowatts. A fish pass will be built to assist salmon to reach Loch Lochy.

Robert H. Saunders, C.B.E., Chairman of Ontario's Hydro-Electric Power Commission, has authorised additional hydro contracts for British equipment to the tune of two million dollars. During his visit to Britain recently with Richard L. Hearn, Chief Engineer, turbine generators ordered from C. A. Parsons & Co. Ltd., Newcastle-on-Tyne, were inspected for the thermal power station being constructed for Windsor, Ontario, by the English Electric Co. Ltd.

Guayabo Hydro-Electric Project

In this article an underground power house of unusual design is described, the conventional method of having a vertical assembly for the turbine generators having been abandoned in favour of horizontal units provided with a draft tube that is also horizontal.

THE Comision Ejecutiva Hidroelectrica del Rio Lempa (generally referred to as the CEL), an autonomous agency of the Government of the Republic of El Salvador, Central America, has commenced the construction of an hydro-electric project on the Lempa River at the Guayabo Rapids (Chorrera del Guayabo). This plant is the first step in the programme of development of the power potentialities of the Lempa River as a means of meeting the country's crying need for electrical power.

The Guayabo hydro-electric power project will be located on the Lempa River about 58 kilometres in a straight line north-east of the capital city, San Salvador, just below the junction with the Sumpul and slightly above the Honduras-El Salvador international section of the river. The drainage area of the river above the site of the dam is about 3,800 square miles.

The land to be inundated by the reservoir covers a total area of about 20 square kilometres or 7.7 square miles, and the reservoir will store about 177,000,000 cu. metres or 144,000 acre feet in the upper 13 metres of depth. This will be sufficient for a regulated flow of 42 cubic metres per second during the driest season and 46 cubic metres per second (1,610 cusecs) in an average year. In addition, it is planned to develop a natural lake, Laguna Guija, for a somewhat greater volume of additional storage.

The general layout is shown in Fig. 1. The dam will be a concrete gravity structure about 64 metres high and nearly 500 metres long with a spillway in the highest portion, across the main river channel, controlled by seven radial steel gates each 12 metres high by 12.5 metres wide. Exceptional flood water will also overflow through a valley to the northward where an earth fill "fuse plug" is provided. The total flood capacity of the gates and the "fuse plug" section is 18,500 cu. metres per second (650,000 cusecs). To the right, or south, of the spillway will be a concrete gravity wing dam extending to high ground, and on the left there will be an air intake structure forming a part of the dam. This structure will contain trash screens and steel intake gates to shut off or admit water, as required, to vertical shaft penstocks with steel liners leading vertically downward to the turbines.

There will be a power station of the underground type, of an interesting and novel design, occupying a chamber excavated in the rock directly below the intakes. Underground power stations proved to be one of the principal features of interest to American engineers attending the High Dam Conference in Stockholm in 1948 and during the subsequent tour of Sweden and other European countries. The European underground stations, however, almost universally follow the same general vertical-unit design which has long been conventional for surface powerhouses. The mere transplanting of the surface type of layout into an underground station does not take maximum advantage of the possibilities offered by an entirely different kind of location.

The Guayabo power station will depart from this practice with several obvious advantages, by using horizontal units as shown in Fig. 2. The advantages gained by this arrangement are as follows:—

1. The power station chamber will be only slightly over one-half as high (and of about the same width) as required for vertical units, thus greatly reducing excavation.
2. The elbows in the penstocks ahead of the turbines, required in vertical units, are eliminated and the penstocks enter the scroll cases tangentially without elbow bends.
3. This setting permits the use of a straight conical draft tube of simpler construction than an elbow tube.

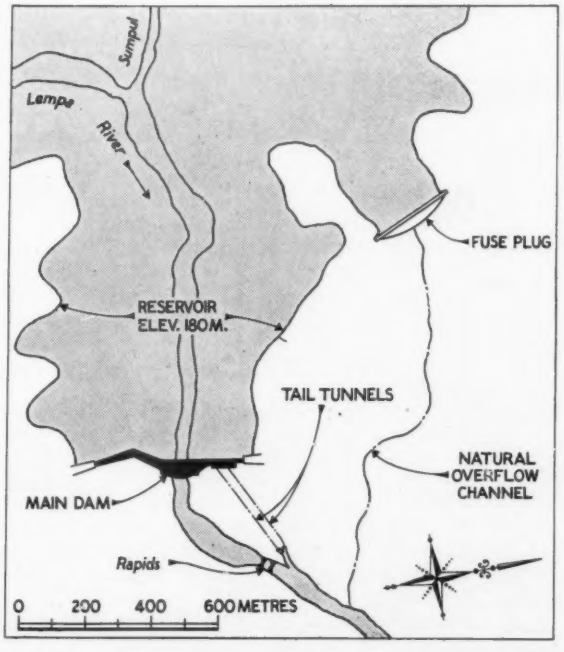


Fig. 1. Sketch map showing relative positions of dam, power station tail race tunnels and storage reservoir

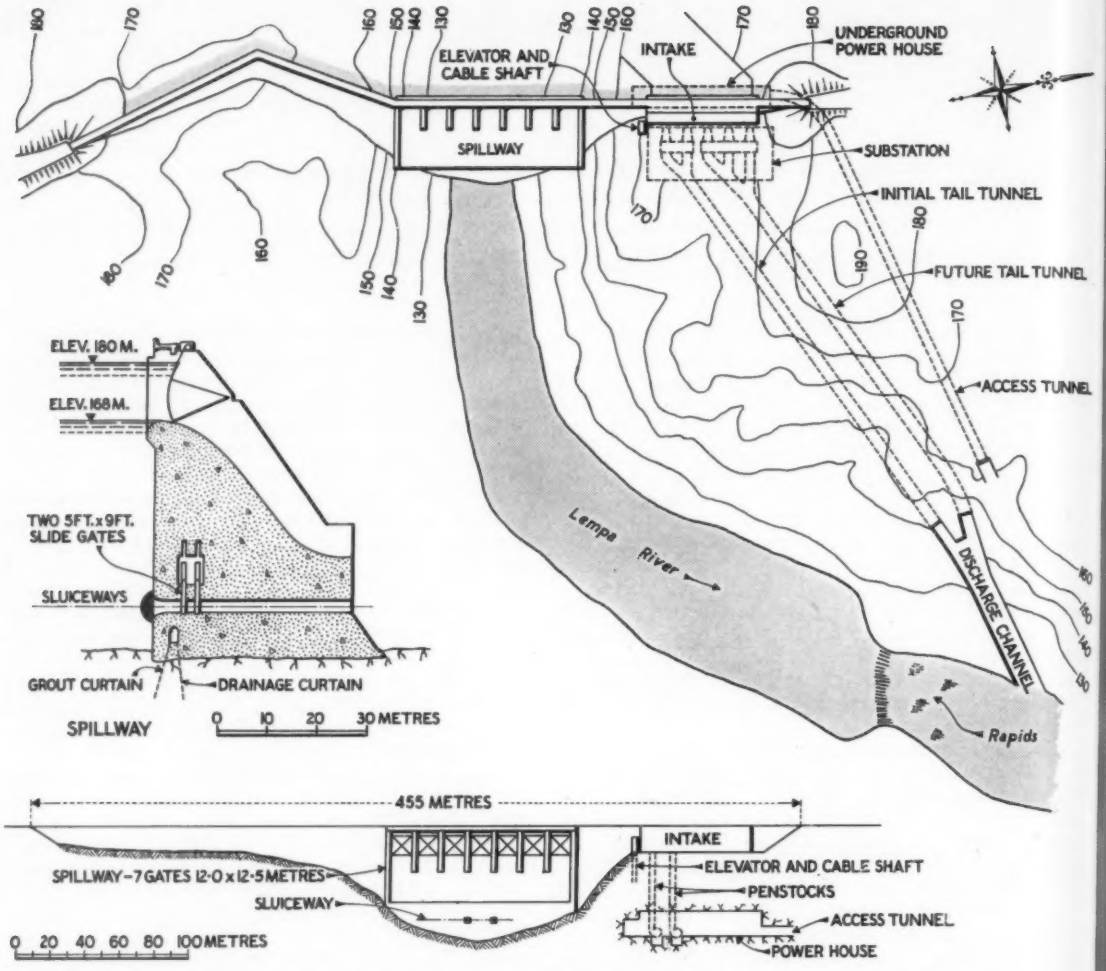


Fig. 2. General plan of site at Guayabo, with elevation and cross section of dam

4. The absence of penstock elbows and of the elbow draft tubes will conduce toward higher efficiency and smoother operation. The length of a horizontal conical draft tube is not a matter of equal concern as compared with vertical units where it affects the excavation depth, but it is in the direction of, and in lieu of, an equivalent length of the required tail tunnel.
5. The time of construction will be materially shortened. Instead of some sixteen or more pours of concrete from foundation level to generator floor, the generator can be founded nearly on bedrock after only one or two pours of concrete. Turbine embedded parts can be lowered through the penstock shafts. Turbines and generators can thus be installed simultaneously.
6. By using an intermediate section of shaft it can be so arranged that the turbine parts can be removed without disturbing the generators.

The only apparent disadvantage is that the movable parts of the turbine will need to be moved horizontally for assembly and dismantling without the benefit of the crane. For this purpose special handling devices will be required which will permit the turbine parts to be moved out to within reach of the main crane. The turbine approach tunnel can be of Gothic section with high enough arch to accommodate an overhead trolley beam with chain blocks; a special car or dolly can be provided to run on rails underneath the shaft; or the entire head cover assembly (with runner) can be designed with its own wheels attached to integral brackets and travelling horizontally on rails embedded in side walls and floor of access tunnel.

Alternatively, the turbine approach tunnel could be eliminated and the turbine head cover set substantially flush with the generating room wall but this would require the penstocks to be embedded in vertical grooves in the rock wall and thus interrupt the continuity of the support of the roof arch and otherwise complicate the structure.

This type of power station, because of its low elevation related to tailwater would not be practicable for an outside or surface powerhouse with a great

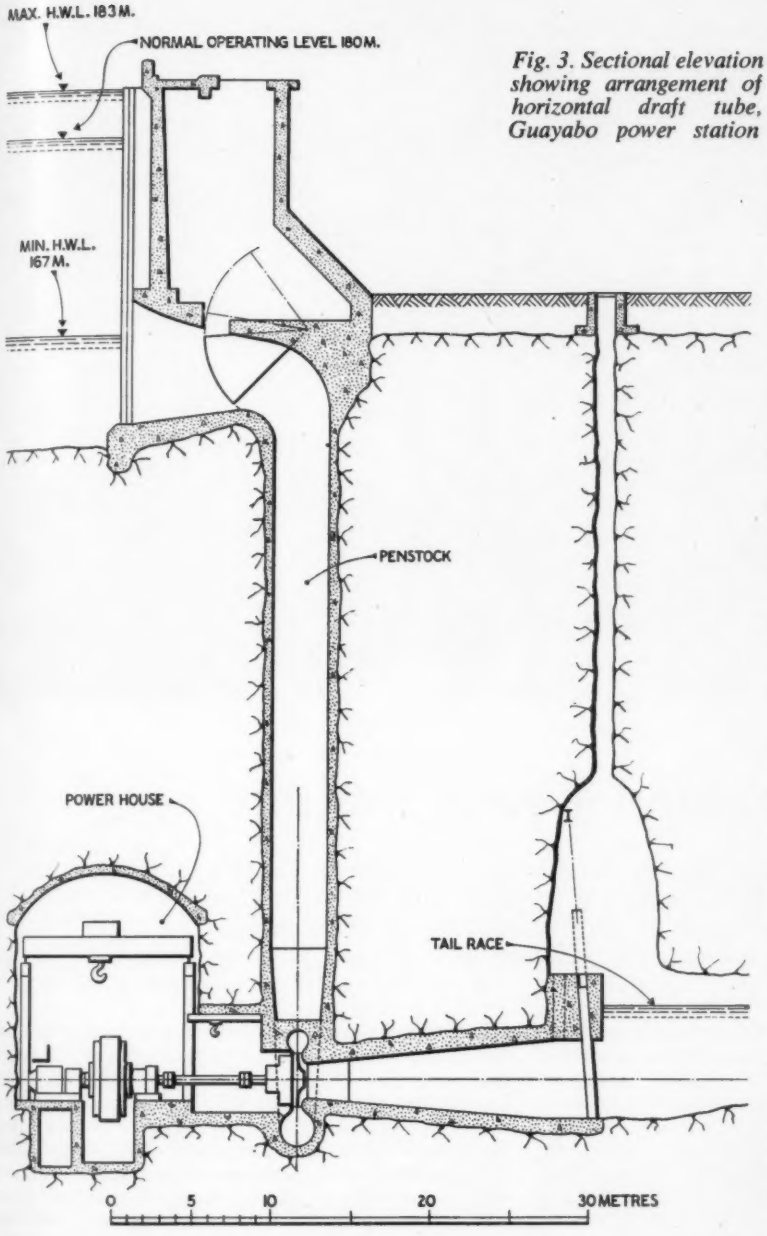


Fig. 3. Sectional elevation showing arrangement of horizontal draft tube, Guayabo power station

tailwater rise (in this case a possible 70 ft.) as it would be too costly to design the exposed building against outside pressure. But this objection does not apply to the underground chamber for which the natural rock forms the support. Only the tailgates would be directly exposed to the high tailwater and they are at the same elevation as with a conventional vertical unit. The turbine head cover is the only power station surface directly exposed to water pressure, which would also be the case with a vertical unit.

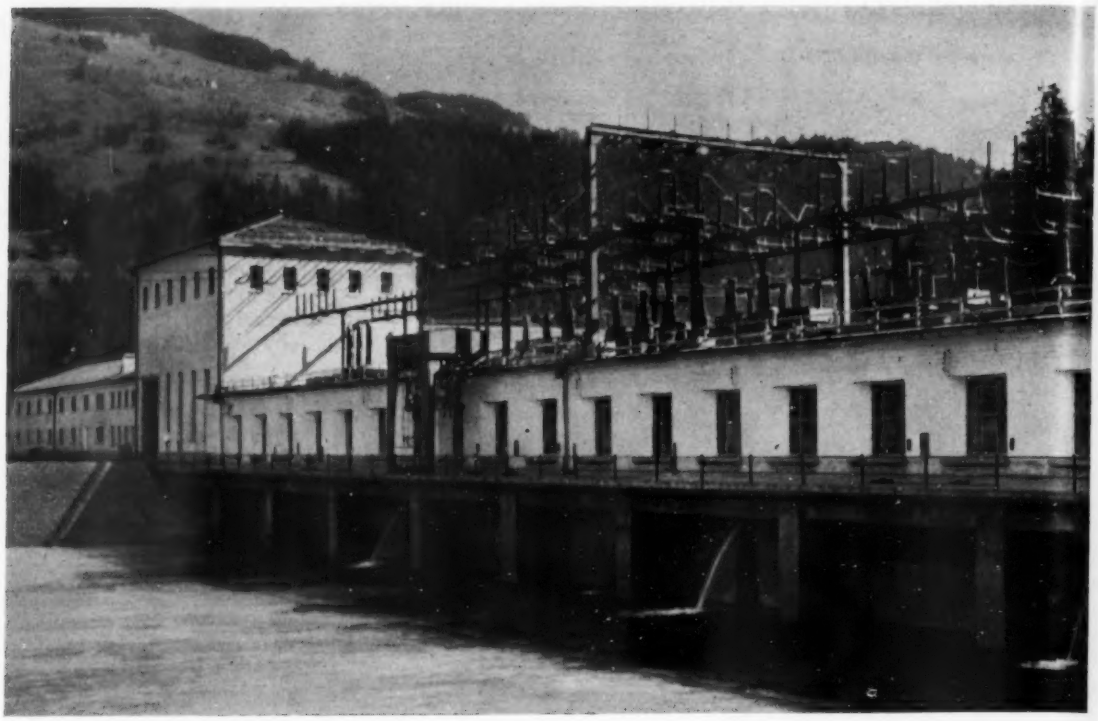
The power station will be equipped initially with two horizontal shaft hydraulic turbines fed through the vertical penstocks described above, driving two horizontal generators and with extra floor space for erection and dismantling, switchgear and operating room. The turbines will be rated each at 21,000 metric horsepower at a head of 164 feet or 50 metres. The generators will be rated 16,667 kVA at 90 per cent. power factor, 200 r.p.m., 60 cycle, three phase. The Guayabo station will have a normal capacity of 30,000 kW, with the initial two units, decreasing to about 26,000 kW when the draw down is at the lowest elevation for useful storage. The two horizontal conical draft tubes discharge into a single tail tunnel about 280 metres long followed by open cut for about 70 metres. The net head will vary from about 56 metres or 184 ft. at full reservoir and full-load flow, down to about 41 metres or 134·5 ft. at low reservoir elevation. Access to the power station will be through elevator or inclined tunnel.

A step-up substation will be located just downstream of the intake and directly over the power station, fed by low tension cables from the generators below. This will contain transformers for feeding the 115,000 V outgoing transmission lines, to connect with San Salvador and other load centres for which receiving and distributing substations are planned.

The Consulting Engineers for the design of the installation, the supervision of the construction of the project and the initial operation of the plant are the Harza Engineering Company of Chicago, Illinois. The contractors for the general constructional work are the J. A. Jones Construction Company of Charlotte, North Carolina; the turbines are being manufactured by Theodore Bell & Cie and the generators by Brown Boveri & Company, both of Switzerland.

Lerwick Generating Station

This Constructional Scheme, No. 54, which has been confirmed and laid before Parliament in accordance with Section 5 of the Hydro-Electric Development (Scotland) Act, 1943, provides for a diesel generating station with an installed capacity of 6,000 kilowatts at Lerwick, Zetland. This station is required to deal with the growing demand for electricity in the Shetland Isles, off the coast of Scotland.



Rodund Power Station

In describing this installation, Professor H. Gerber, of the Swiss Federal Institute of Technology, Zurich, refers to some of the problems which are incidental to the use of high pressures with Francis turbines.

IT is understandable enough that endeavours should be made to apply Francis turbines to ever increasing heads, in much the same way that the range of application of the Kaplan runner should have been increased, as obvious economies are realised in virtue of the higher speeds secured. Although for the same hydraulic data, the efficiency curve of a Francis turbine is not so flat as that of an impulse wheel, it does reach a higher maximum and combines a higher speed with very much smaller dimensions. This higher speed not only influences the cost of the turbine but also that of the generator, while the smaller dimensions are of importance in enabling the cost of power house to be reduced—a point of particular importance when the equipment is installed underground. Moreover, compared with impulse wheels the Francis runner enables the whole range of head down to the tail-race level to be utilised.

Although some diffidence was at first felt about applying the Francis turbine to heads of over 250 m. (820 ft.), this was chiefly owing to operational considerations. Certainly, in high-pressure Francis machines with their relatively narrow runner wheels, the clearance losses, reckoned on a percentage basis, are of importance and the behaviour of the labyrinths under the influence of the operating pressure had necessarily to be carefully investigated. With the knowledge we possess to-day, however, and the use of appropriate materials for the labyrinths, this initial hesitancy has been quite overcome. Particularly is this the case when, as is usual in considerable installations, there is an artificial lake in which any sand or other abrasive material can be removed from the operating water to a sufficient degree to ensure that the labyrinths will function satisfactorily for long periods.

The application of Francis turbines to high heads becomes of special interest when pump storage systems are under consideration because for the same hydraulic data the turbine approaches to within 30 per cent. of the speed that the pump requires. If the delivery head of the pump is high it is usually necessary to provide a positive head on the suction side in order to reduce the number of stages required and to

Our titlepiece gives a view of the Rodund Station which is equipped with four Escher Wyss horizontal Francis turbines of 66,200 h.p. each under a net head of 346 metres

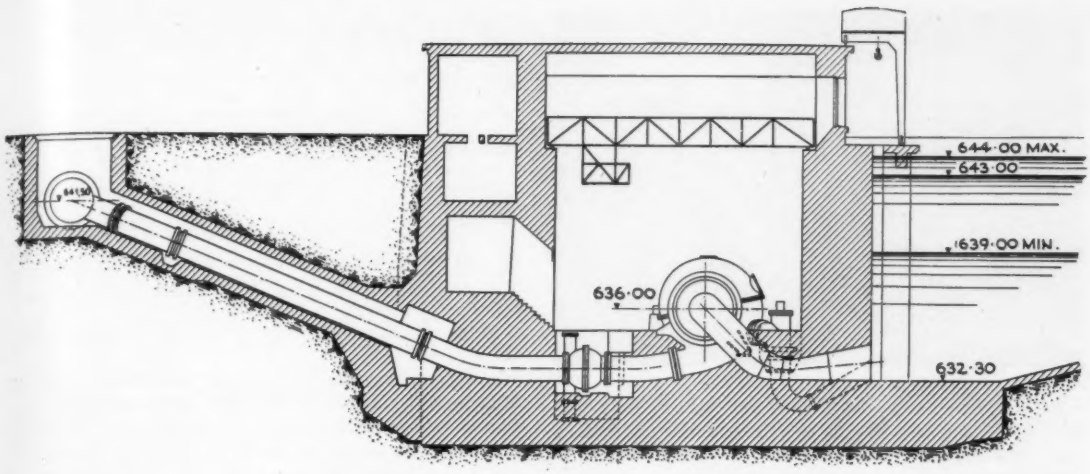


Fig. 1. Classic arrangement of the sets at Rodund: as this scheme provides for pump storage and the pumps require a positive head on the suction side, the adoption of impulse turbines was impossible, especially with a horizontal arrangement

increase the specific speed, and thus augment the efficiency. With such requirements to meet, the impulse turbine is quite out of the question, particularly where a horizontal arrangement is concerned.

A power station in which all these factors had to be considered is that at Rodund where the Vorarlberger Ill-Werke of Breganz are harnessing the waters of the River Ill. Here, up to the present, four stages have been developed in a scheme which envisages the utilisation of a total head of 1,391 m., representing the difference between the high-head impoundment at 2,030 m. (6,550 ft.) to the 639 m. (2,080 ft.) level in the Rodund tail-race compensating reservoir. The Francis turbines at Rodund are designed to operate at a head range of between 327 m. (1,068 ft.) and 346 m. (1,164 ft.). Under the optimum condition a useful output of 66,200 h.p. is developed at 500 r.p.m., the turbines being the largest that have yet been designed for such a high head. All four turbines are supplied by individual pipe lines branching from a common reinforced pressure tunnel having a total length of 805 m. (2,613 ft.) and driven at an inclination of 30 deg. The turbines, which are of Escher Wyss make are of the spiral type, are coupled to 53,000 kVa, 3 phase generators and run very quietly. Each set is provided with two bearings only, so that the generator bearing on the turbine side has to accommodate all reactions of the overhung turbine runner.

A rotary valve is provided at the spiral inlet of each set, which is also furnished with a relief valve to avoid water hammer effects. Apart from the servo motor controlling the guide apparatus all the control equipment is housed in the same casing.

According to the level of the tail-race, the turbines operate with a back pressure corresponding to a head of 3 to 7 m. of water, measured from the centre line of the turbine shaft. Quietness of operation is assured by a separate aeration system, the air being introduced in accordance with the tail-race level and load conditions. A small separately driven compressor is in service to provide the necessary air.

As a consequence of the war, efficiency tests could not be carried out until March, 1948, when the guarantee period had expired. For making these measurements a rigid cross for supporting the current meters was fitted at the commencement of the horizontal distribution pipe, so that the water measurement could be carried out simultaneously with 21 current meters on two diameters of D = 2·7 m. The Ott current meters, provided with pressure balancing bores, proved their merits to the full under the high pressure (350 m.). All current meters were duly calibrated and the signals for the current meters were synchronised with a chronograph. For measuring the head, a weight pressure gauge and spring pressure gauge were available for checking purposes, both of which could be adjusted on site with the aid of the static head. The generator output was measured at the terminals with a complete set of precision instruments and transformers. The results of the test floor measurements on the generator were duly considered in calculating the output of the turbine at the coupling. Altogether,

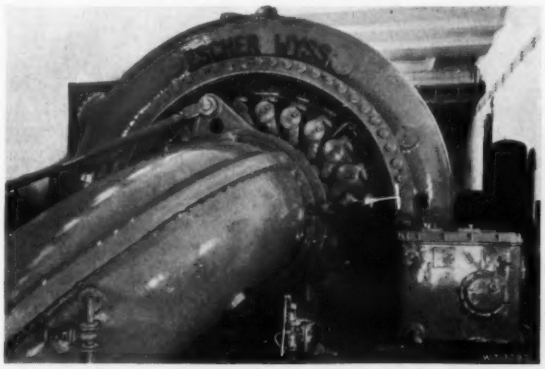


Fig. 2. Draught-tube side of 66,200 h.p. back pressure Francis turbines. Aeration of the draught tube is effected by the admission of compressed air controlled by an inlet valve governed from the regulating ring

Fig. 3. Pedestal bearing on the turbine side, serving also as thrust bearing

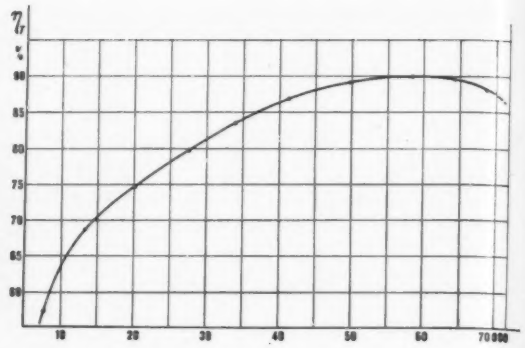


Fig. 4. Results of efficiency measurements based on the guarantee conditions H = 346 metres, n = 500 r.p.m. These measurements were made after 14,900 hours running and exceed the guarantee by about 7 per cent.

the efficiencies were measured at ten different loads, lasting seven minutes in each case. Moreover, the water measurements were carried out with the generator excited and unexcited and the leakage loss determined with the guide apparatus closed.

The results of the measurements, based on the highest guaranteed head of 346 m., may be noted from Fig. 4. For the chosen output limitation the turbine develops 71,300 h.p. and the maximum efficiency is 90 per cent.

When judging these results it should be borne in mind that the tests could not be carried out on the turbines in the new condition, but only after 14,888 hours of operation during which 459 million kWh had been produced. The inspection of the turbines made prior to the tests proved fully satisfactory and no overhauling work had to be done. The runners, labyrinth rings and draught tube protection rings, all of stainless cast-steel, were still in good condition. Only the labyrinth clearances had been somewhat widened owing to the action of the fine glacial sand carried by the water. This wear also explained why an efficiency of about 92 per cent., such as could be expected from a turbine of this kind when quite new, was not obtained. However, such an efficiency can be expected from new machines of this size when the existing results with model turbines can be duly put into effect.

From the foregoing remarks it is evident that the observations made at the beginning of this article can successfully be put into practice at the Rodund Power Station. The adoption of high-pressure Francis turbines has proved advantageous in every respect.

As regards the sensitivity of Francis turbines to operating water containing sand, the results obtained at this plant seem to us to prove very well that for such conditions they are no more sensitive than impulse turbines. From published data it will readily be ascertained that at important power stations employing impulse turbines, overhauling work usually has to be carried out before each winter period and that the annual replacement of needle points, nozzles and mouth pieces is necessary to preserve efficiency. Without doubt, such repairs and replacement are easier to make in the case of impulse turbines, but on the other hand they are needed much less frequently in Francis turbines.

In conclusion it should be mentioned that it is proposed to install two storage pumps of 52,000 h.p. later on.

British Honduras

In the House of Commons Mr. J. Griffiths, the Colonial Secretary, outlining developments in British Honduras, said that an investigation was at present being made of hydro-electric possibilities in the Stann Creek and Belize areas.

Mr. Heathcoat Amory asked the Minister of Fuel and Power if, in view of the prospect of a long term shortage in coal supplies in Great Britain, he would investigate the potentialities of further hydro-electric projects beyond those at present planned, including medium and small-scale schemes.

Mr. Noel-Baker said that the British Electricity Authority had under consideration a number of hydro-electric projects of small and medium size, and investigations were proceeding to see whether they would be economically sound.

The Scottish Office has issued, as a White Paper (H.M. Stationery Office, price 2d.) details of Constructional Scheme No. 56, concerning Stornoway generating station of the North of Scotland Hydro-Electric Board. This scheme provides for the construction of a diesel generating station with an installed capacity of about 6,000 kilowatts at Stornoway in the island of Lewis. The station is required to deal with the growing load in Stornoway and throughout the island of Lewis. The estimated capital cost of the scheme is £336,000.

Elastometric Engineering Examples. Under this title the Andre Rubber Co. Ltd. have issued a handsomely produced brochure to show the many applications of rubber to engineering needs; these applications are too many to enumerate but include resilient gear wheels, anti-vibration mountings, torsional vibration dampers, flexible couplings, and protective coverings for pipes, large vessels and other forms of steelwork.

Power Conference at New Delhi

By JOHN WARNOCK

The World Power Conference assembled at New Delhi on 10th January to consider and discuss in three Sectional Meetings a series of Papers which had been submitted on specific questions and on which the pooling of information would be useful in order to further the technique of power development and allied subjects. The Conference was followed by a Study Tour of engineering works and other points of interest over a considerable part of India.

BEFORE proceeding to a description of these meetings and the subsequent study tour, mention should be made of the preceding Conference held at Bombay of the International Association for Hydraulic Research, between 2nd and 5th January. This was followed by its own study tour comprising visits to Khapoli works of the Tata hydro-electric power system, near Bombay, the reservoir extension based on the new Vaitarna dam for the water supply of Bombay and the Meteorological and Hydraulic Research Stations in Poona and neighbourhood.

In view of the considerable activities now taking place in India, on the construction of large works for irrigation and hydro-electric power, it is appropriate that these conferences should have been held in that country at present. The engineers responsible for the general direction of the irrigation and water power branches of engineering in India are fully alive to the importance of research in solving the various hydraulic problem with which they have to deal and a number of important hydraulic research stations are now operating in the country. The station at Khadakvasla near Poona, Bombay, has been in operation since 1916, and is making important contributions to hydraulic research.

The Papers considered at the Conference in Bombay were largely concerned with such problems of interest to India, notably the silting of canals, rivers and reservoirs, and the means of preventing deposition.

The World Power Conference at New Delhi comprised meetings of the Fourth Congress on Large Dams, the Sectional Meeting to consider the general utilisation of electricity, and the first Plenary Session of the recently formed International Commission on Irrigation and Canals. It is appropriate to mention here that the Indian Government had also staged an International Engineering Exhibition at New Delhi which was opened by the Honourable Shri N. V. Gadgil, Minister of Works, Mines and Power of the Government of India. This Exhibition will run for some weeks.

The Exhibition, as its name implies, was international in character, and the exhibits shown were drawn from many countries. Comprehensive exhibits of plant and constructional equipment peculiar to Indian needs were staged by many firms in which Great Britain was quite well represented, but the main part of the Exhibition was devoted to models concerned with irrigation and hydro-electric power. Some of the Indian States had very fine model exhibits of irrigation and power schemes either in hand or contemplated and notable exhibits were also staged by certain European countries, America and Northern Africa. Great Britain was represented by a small stand showing our present development of electricity supply, generated both thermally and by water power, with model and pictorial exhibits of our latest practice.

The Joint Session

A joint Opening Session took place on the morning of Thursday, 11th January, and the several sections of the Conference assembled separately for the submission and discussion of Papers on the following morning. The Fourth Congress on Large Dams held four sessions to discuss the 111 papers submitted on the four questions on which information had been asked:—

(1) Methods of determination of maximum water discharges from a dam and general arrangements required with capacities of spillways to meet these discharges.
(2) Earth and rock-fill dams, design and construction.
(3) Sedimentation in reservoirs and relative problems.
(4) Concrete for large dams.

In relation to (1), a total of 42 papers was submitted. In some of the contributions, the question was considered of calculating the amount of the largest possible flood likely to occur on a given catchment area, but in discussion it was made clear that an exceptional flood occurring, say, once in 1,000 years could not be calculated on an empirical formula and it would be better to rely on experienced judgment based on as long-term data as possible. Various types of spillways on dams were discussed including the "glory hole" and siphon types. It might be added that in the research stations, large-scale experiments are in hand with siphons, including the domed, volute type.

Earth and rock-fill dams were discussed in 23 papers, and many different designs with and without core walls were considered. Apart from sound design, it is clear that proper materials are necessary, with adequate consolidation and ample drainage arrangements in the area of the structure behind the impervious section of the dam.

Silting was dealt with in 16 papers; this is receiving considerable attention in India and silt excluders of various types are under active investigation in the research stations. Some papers discussed the theoretical aspect of silt travel while others dealt with the conditions in actual schemes; the serious aspect of

silting in reservoirs was well illustrated in papers submitted from France and Algeria. It seems clear that the exclusion of silt from storage reservoirs by an arrangement of settling pools is probably the best solution and constitutes the only real one for those rivers which carry large concentrations, unless provision can be made for silt accumulation in the reservoir. For instance, on the Mettur Dam project in the State of Madras, provision was made in the original design for raising the dam height by ten feet should this become advisable on account of the loss of storage through the accumulation of silt in the reservoir. Multiple sluice gates do not form a complete solution on a hydro-electric power scheme.

Concrete

The papers submitted on concrete for large dams considered the various expedients available for reducing setting temperatures in pours deposited in large volumes. In the discussion on this subject, low cement content concrete was not favoured by speakers from Scandinavia and Switzerland in view of past experience in these countries. A type of buttress dam tried in Sweden was cited as allowing an adequate cooling surface effect. A low-heat cement has given good test results and is favoured when obtainable in sufficient quantity for extensive constructional work. It is already in use on important dam structures.

Papers submitted to the Sectional Meeting of the World Power Conferences dealt mainly with power utilisation in agriculture and co-ordination of power supplies in the development of industry, including railway traction. In one paper, however, the application of automatic hydro-power plant to the run-off of irrigation canals was discussed, particular reference being made to an installation in Algeria.

The International Commission on Irrigation and Canals had convened their first Plenary Session at the World Power Conference Meeting. Some Papers submitted were of interest from a hydro-electric point of view but need not be reviewed here as they were duplicated to some extent by Papers submitted at New Delhi.

Delegates taking part in the Study Tour were accommodated in two trains made up of sleeping cars with restaurant cars attached. The trains travelled at night and remained at a station during the day, while tours, generally by 'bus, were arranged to the various points of interest. The itinerary was extensive and occupied some sixteen days of travel.

India is very actively engaged at the present time to augment its agricultural resources by means of irrigation. Very large schemes are in hand involving the construction of reservoirs and irrigation canals. These schemes also include for hydro-electric generation where suitable pressure heads are available. The Study Tour was arranged to include visits to various schemes under construction as well as to completed works.

The uneven incidence of rainfall in India, caused by the monsoon-type climate, creates the necessity for very large storage reservoirs. Those inspected during the tour were remarkable for their masonry construction and great length. Concrete gravity dams are also being constructed or under consideration: on the River Sutlej, in the Punjab, for instance, it is proposed to erect a dam having a height of 680 feet. Earth-fill dams are also being constructed as extensions to masonry or concrete structures, the latter providing the spillways and power-generating sections of the project. As a corollary to the water storage arrangements, a large programme of canal construction is proceeding.

A short survey might be given of the more notable engineering works seen during the Tour. One of the earlier visits was to the Upper Ganges Canal, still a notable construction though now nearly 100 years old. The canal takes off the River Ganges, near the ancient and sacred City of Hardwar, Uttar Pradesh, and irrigates an area of some 1½ million acres, its course, including branches, extending some 200 miles.

At Bhakra, on the River Sutlej, construction on a large irrigation and hydro-electric project has been started. Two bypass tunnels each 50 ft. finished diameter, and half a mile long, are in hand on each side of the river to make provision for dealing with the river water during the construction of the main concrete dam which is to be 680 ft. high and constructed in a convenient gorge. About eight miles further downstream, a diversion dam with head works at Nangal will be the starting point of a main irrigation canal which will have a discharge capacity of 12,500 cusecs and which will irrigate an area of 6½ million acres.

At the Bhakra Dam, two power plants are planned for a total generating capacity of 750,000 kilowatts, and in the Bhakra Main Canal advantage has to be taken of two 100 ft. falls in the course to install plants of 144,000 kilowatts capacity each. Construction of one plant has already begun.

Land Reclamation

In the Damodar Valley, in the State of Behar, to the west of Calcutta, an interesting development is taking place which bears a resemblance to the T.V.A. schemes in the United States. The scheme includes irrigation qualities and water-power development, and will enable the reclamation of large tracts of land which have been depleted through soil erosion. Largely as a result of methods of tillage being followed with no proper crop rotation, the soil has been denuded either by the wind or the deluges of the monsoon rains. An experiment is in progress at the site of the new Tilaija Lake, where a concrete gravity dam of medium height is under construction to form an artificial lake (or "tank" in the Indian term), to provide both irrigation and power. Eight such lakes are included in this project to irrigate one million acres and to provide 240,000 kilowatts of power. As coal is also available in the district thermal power will also be provided. In an adjacent area to the lakes the ground is being rehabilitated making use of heavy earth moving equipment; small local reservoirs are being formed in favourable positions, with earth dams, complete with spillway arrangements, to provide local irrigation, and model villages are being built to house the communities displaced from the lake sites. In addition, model farms have been formed where up-to-date methods of tillage are being demonstrated, cropping two or three crops a year, to show just what can be accomplished.

The scarcity of fuel over most parts of India has led to a more or less universal use of dried cow manure as a fuel with resultant loss to the soil. Efforts are now in progress to rectify this deficiency by the manufacture of artificial manures on a large scale,

and these measures allied with water obtained by irrigation, should assist towards rectifying the present grain scarcity.

The valley of the River Mahanadi, further west from Calcutta, in the State of Orissa, has been the scene of severe famines in years of low monsoon rains. It has also seen the occurrence of devastating floods in periods of heavy rain. This trouble is now to be rectified through a system of flood-control reservoirs, which will provide storage for both irrigation works and hydro-electric developments. An inspection was made of the Hirakud works where a dam in mass concrete, about 160 ft. high, is being constructed in conjunction with earth-fill sections on either side to a total distance of three miles. Under this proposal, 20 million acres of land will be irrigated and hydro power totalling some 325,000 kWs will be developed in two power stations. This scheme is in its early stages of construction.

A project of extensive irrigation and power development is in hand at Tungabhadra dam, on the River Cauvery, which forms the boundary between two states—Madras and Hyderabad. This work is being undertaken jointly by the two states and a masonry dam is under construction having a maximum height of 160 ft. and length of nearly 6,000 ft. As an extension to the main dam, an earth dam and a composite masonry-earth dam are to be built.

The use of masonry for dams of medium height is much practised in India, as suitable materials are generally at hand. Granite is fairly extensively used, with lime mortar as binding material. Limestone or Kankar (a lime material in nodular form) with a lime content of around 60 per cent., is burnt in kilns generally adjacent to the dam site. Sukri, a burnt clay brick, finely ground, is used as an ingredient for the mortar either in conjunction with sand or neat; a mix of lime, sand, Sukri in equal proportions is common for main bulk dam work, with richer mixes for more important sections.

Portland cement is manufactured in India and is used in very large dams. Its expansion difficulty is a drawback not present in masonry dams built with lime mortar. In the Tangabhadra Dam, Portland cement mortar with a Sukri admixture up to 20 per cent., plus sand, is being used for the forward 9 ft. of masonry, on account of better watertightness, and also for the spillway section of the dam, the valve and gate chambers.

Completed power projects were also visited at Jog Falls on the River Sharavathi, in Mysore State, where a pressure head of about 1,170 ft. will be utilised to drive Pelton wheel turbo-alternators of 120,000 kW. At Mettur, in Madras, a dam 5,300 ft. long and 214 ft. high irrigates an area of 1,350,000 acres and serves a power station having a generating capacity of 40,000 kW.

This brief record of the World Power Conference would not be complete without paying tribute to the amazing kindness and attention paid to the delegates by the Indian National Committee and their able coadjutors. We could not have wished for better guidance and help on the extensive itinerary of visits which the delegates were able to accomplish. It has truly been a memorable experience and delegates will take with them many happy recollections of the World Power Conference in India of 1951, and the general friendliness of the Indian people.

A Canadian Development

THE Aluminium Company of Canada has awarded to the Fraser - Brace Engineering Company of Montreal, a contract for the construction of a new hydro-electric development in the Saguenay region of Quebec, according to a recent statement by Mr. Leland B. Fraser, president of Fraser, Brace & Company, of New York, and a director of the associated Canadian firm.

Work will start immediately on the new project, which will play a substantial role in increasing the aluminium output of Alcan, now the largest producer in the world. The new development is located at the Chute du Diable (Devil's Fall) on the Peribonka River, 30 miles above the river's entrance into Lake St. John. This lake is at the headwaters of the Saguenay River, 230 miles north of Montreal, in the central section of Quebec. A dam and powerhouse with a total capacity of 200,000 h.p. will be built. The project will call for road improvement in an uninhabited region and will also require the excavation of 450,000 cubic yards of rock and the pouring of 275,000 cubic yards of concrete. The first 50,000 h.p. generator is scheduled for completion by May, 1952, with the others following at the rate of one a month.

The Peribonka project will increase by 10 per cent. the water power facilities of the Saguenay area, which already has an installed capacity of 2,100,000 h.p. This figure is 18 per cent. of the total for the Dominion. The Saguenay region is thus a major contributor to the power facilities of Quebec, which now has 53 per cent. of the developed water power capacity of Canada. The Saguenay area also includes the largest single hydro-electric development in the Dominion, the 1,200,000 h.p. Shipshaw No. 2 Powerhouse, which supplies the Arvida plant of the Aluminium Company of Canada. This installation is the world's largest aluminum producing plant. In addition to Shipshaw No. 2, at least 18 other hydro-electric developments are spread throughout the region.

Mr. Fraser noted that with the completion of this contract the Fraser-Brace Companies will have installed 2,000,000 h.p. of hydro-electric capacity at a total cost of over $100 million. This work has included 25 separate hydro-electric projects. The contract will be the eighth which the Fraser-Brace Companies have undertaken for the Aluminium Company of Canada.

Fixing Devices. A particularly useful brochure produced by the Rawlplug Co. Ltd. mentions the many types of fixing device manufactured by this firm.

Rock Drill Lubrication. Under this title C. C. Wakefield & Co. Ltd. present a comprehensive survey of the various types of drills and kindred tools in current use, their operation and proper lubrication.

High-frequency Vibration. Adequately - illustrated pamphlets received from Westwool Limited discuss the advantages of their high-frequency vibration tables for both concrete consolidation and research, and their high-frequency hand-type vibrators.

Faults on Units

By S. FERRY

Service de la Production Hydraulique, Electricité de France

An analysis of faults on hydro-electric units has recently been carried out for the purpose of preventing, if possible, a recurrence of similar troubles, and of ascertaining the most frequent causes behind the occurrences of the various faults.

FROM a total of a thousand units which were considered for this purpose, there have been in 1949 forty-three incidents concerning turbines, including shafts and bearings, and 104 concerning alternators. The duration of the shut-downs measured in terms both of time and loss of energy through plant out of commission, has been 11,500 hours and 60,000,000 kWh in regard to turbine faults, and 47,500 hours and 9,000,000 kWh in relation to alternator troubles. Of the losses of energy production imputed to the turbines 53,000,000 kWh came from two bearing troubles on important units which had only recently been put in service.

The analysis of these incidents is given in Table I.

TABLE I

Turbines		
Foundations and bearings	15	incidents
Troubles relating to clearance, friction and rubbing within the spiral casing of Francis turbines	8	,,
Breakage of blades in Francis and Pelton turbines	4	,,
Failures of oil pumps for governor control	9	,,
Various incidents relating to governors or governor gear	7	,,
Total	43	incidents

By periodical visual inspection of the thrust and guide bearings it appears possible to reduce the onset of the first two categories. Regarding incidents relating to oil pumps for the governor gear, it seems, in general, that these troubles are caused by constructional faults and in many cases the materials used in recent installations have not been properly adapted to the severe service conditions.

Certain difficulties which have arisen through cracks in the buckets of certain Pelton wheels (a type of incident which does not appear in the statistical table above) must also be noted. This matter, which relates to the choice of the constructional material and to its heat treatment, is now being made an object of careful study.

The great majority of incidents relate to the windings of the stator. Fatigue of insulation due to decay seems to be one of the causes, since three-quarters of these incidents relate, in effect, to windings which have been more than 15 years in service.

TABLE II

Alternators		
Faults relating to the body of the stator	44	incidents
Short circuits between windings	29	,,
Short circuits between phases of the framework	13	,,
Faults relating to the body of the rotor and to the windings	8	,,
Various mechanical troubles	10	,,
Total	104	incidents

As a result of these considerations, the *Service de la Production Hydraulique* has now established a programme of renewing the windings on the stators on a systematic plan, related to the possibility of taking machines out of service; the necessary material has already been acquired and placed on the various sites. In addition, the examination of conditions in which these alternator faults have occurred, has shown that they have often been aggravated by the insufficiency of the protective gear. An effort is also being made to ameliorate this condition in older installations.

HYDRO-ELECTRIC POWER IN PORTUGAL

THE first of three turbo-alternator sets at Castelo do Bode Hydro-electric Power Station on the River Zezere, about 90 miles north-east of Lisbon, was started recently by the President of the Republic of Portugal, Marshall Antonio Oscar Fragoso Carmona. The ceremony marked an important stage in the development of hydro-electric power which is being sponsored by the Portuguese Government.

All the power plant and electrical equipment at the power station as well as the switchgear at the adjacent sub-station have been manufactured in England jointly by The English Electric Company and Metropolitan-Vickers Electrical Company. These companies set up an organisation comprising members of their respective export companies and known in Portugal as "The British Group" to carry out the project. Under this joint arrangement the resources of the companies were pooled to produce some of the largest electrical equipment ever made in Britain.

When complete the power station will be capable of supplying 156,000 kilowatts at 15,500 volts, to be delivered to the Portuguese grid at 165,000 volts. Among the more important items of equipment are three generating sets, each consisting of a 73,000 h.p. vertical shaft reaction-type water turbine driving a 57,400 kVA generator at 214 r.p.m.; three 52,500 kVA 15·5/165 kV three-phase transformers; and 165 kV switchgear incorporating air-blast circuit breakers. The sub-station is being equipped with 165 kV air-blast switchgear.

Wagon Drill. Holman Bros. Limited have sent us a well-produced folder describing their trailer-type transportable drill unit.

Inspection Handlamps. An illustrated leaflet received from Nife Batteries gives relevant details regarding their type G10 inspection safety lamp.

Canada's Expanding Demand and Supply

By Our Special Correspondent

IN a record year for hydro-electric progress in Canada the provinces of Ontario and Quebec naturally occupy the principal positions. In new capacity a total of 1,037,275 h.p. was added, a figure that in the past has been approached only by the wartime year of 1943, when the gigantic Shipshaw plant in Quebec was completed.

The advance in Ontario during 1950 represents the culmination of the biggest post-war construction programme of the Hydro-Electric Power Commission of Ontario, especially in relation to the great des Joachims plant on the Ottawa River. The first two units here were placed in commercial operation on July 6 and by early December six units were operating. It was expected that by the end of February this year two further units would be completed, the eight units having a total installed capacity of 480,000 h.p. The Chenaux generating station (installed capacity 160,000 h.p.), La Cave (192,000 h.p.), Pine Portage (160,000 h.p.), Sir Adam Beck No. 2 (600,000 h.p.) and Richard L. Hearn (400,000 h.p.) are other projects on which a wide variety of development or preparatory work has been done.

Transmission Lines

In the associated work of transmission and distribution there has also been extensive additions. These include 939 miles of 230 kV line, 547 miles of 115 kV line, 384 miles of 13·2 to 44 kV line and 2,100 miles of rural lines. It was estimated that by the end of 1950 the number of farms receiving service in Ontario would be increased to 114,500. The big task of changing distribution in Southern Ontario from 25-cycle power to that of the standard 60 cycles has made good initial progress, but completion of this work will take several years.

In Quebec province the Shawinigan Water and Power Company's addition to the La Trenche plant on the St. Maurice River is another of Canada's major achievements during 1950. Two units each of 65,000 h.p. went into service late in December and three more units are expected to be in operation early this summer, the plant being designed for an ultimate capacity of 390,000 h.p. Under an accelerated construction programme two units each of 55,000 h.p. were started by the Quebec Hydro-Electric Commission at Beauharnois, on the St. Lawrence River and four more will be installed this year. Here again, as in Ontario, the power-distribution Commission has continued to build high-voltage lines between Beauharnois and Montreal.

British Columbia

Next in importance come the provinces of British Columbia and Yukon Territory. Here there is a fairly steady increase in the demand for electric power due to the growth of industry and population. Development of 33,000 h.p. in two units at Whatshan Lake by the Power Commission has been rapid and operation is scheduled for next month, with an ultimate doubling of the plant capacity. In the case of the Clowhom Falls development, on the river of that name, the initial head of 130 ft. may later be brought to 165 ft. by raising the dam.

The British Columbia Electric Railway Company has embarked on the modernisation of its Lake Buntzen No. 1 plant, and will replace seven old units (total capacity 28,140 h.p.) by a single new unit rated at 70,000 h.p. At the Bridge River development the height of the La Joie storage dam has been raised to provide storage capacity to the extent of 285,000 acre feet. In the distributive field an extensive programme of substation construction was carried out in Vancouver, in the Fraser Valley, and on Lower Vancouver Island. In Yukon Territory, building on the Mayo River of a development with an initial capacity of 3,000 h.p. was begun by the North-West Territories Power Commission to serve the silver-lead mines in the district. Construction of the dam and power house is scheduled for this year.

In Alberta, Saskatchewan and Manitoba 1950 was a year of steady progress without any highly spectacular features. There has been expansion of the transmission network in each case. Manitoba's, for example, consisted of 200 miles of 66-kV line, 78 miles of 33-kV line and 3,363 miles of farm line. In Nova Scotia the Power Commission completed its 12,800 h.p. scheme in two units on the Mersey River. Main transmission lines were extended by 20 miles, and the rural lines by 350 miles. The New Brunswick Electric Power Commission has undertaken a development of 27,000 h.p. at The Narrows, on the Tobique River near its mouth, and this plant is expected to begin operating in 1953.

Vast Resources Waiting

The total installed capacity of water power plants in Canada at the close of the year is listed as 12,654,835 h.p., which represents the development of about 23 per cent. of the total resources of the Dominion. As this brief review indicates new plants and additions during 1950 were well distributed across the country. It is reliably assessed that developments and extensions now under active construction total about 1 million h.p., and those under preliminary construction or definitely planned are tentatively rated at 1,500,000 h.p.

The percentage increase in the demand for primary power during 1950 was about eight—sufficient of itself to account for the marked activity in the field of power distribution.

Copies of the official review, of which this a summary, can be obtained free on application to the Water Resources Division, Department of Resources and Development, Ottawa.

Alternators for Hydro-Electric Power Stations

The enormous post-war requirements for electric power have given rise to a great demand for electric generators, and the object of this article, which has been contributed by the A.C.E.C., Charleroi, Belgium, is to discuss recent installations of the type used in hydro-electric schemes.

THE majority of alternators used in conjunction with water turbines have capacities ranging between 8,000 and 30,000 kVA and speeds ranging from 600 revs. per min. for the smaller machines to 167 for the larger, the respective overspeeds being 1,100 and 495 revs. per min.

For such machines the classic design, including two guide bearings and pivot carried by the upper spider, is difficult to better. Fig. 1 gives a general view of such a machine and other illustrations show some of the phases in the manufacture and erection of the stator and rotor.

The frame (Fig. 2) is in two pieces and is constructed of heavy plates assembled by welding. The lower face rests on a base secured to the foundation, while the upper face supports the star girder and transmits the load to the foundations at four points through the intermediary of rigid stiffeners. The inner face is pierced with openings for ventilation purposes.

The magnetic core is built up of segments of soft iron of high permeability, insulated from each other by a Bakelite lacquer and layered with alternating joints in lots of about 50 mm. width. Two adjacent lots are held at the required distance apart by steel distance pieces, the shape of which is selected to form ventilation outlets of such a form that the load losses of the air circuit in the interior of the active iron are at a minimum. The whole mass of sheets is mounted on the keys fixed to the frame; in order to avoid any displacement, it is tightly secured between the heavy-section laminated steel segment plates by means of bolts. These bolts are situated at the periphery of the sheets —an arrangement which ensures a uniform grip of the magnetic core and prevents all vibration. The open slots intended to house the winding sections are arranged in the interior of the core. Fig. 3 shows the winding, which is composed of sections shaped to template and placed to straddle in the slots of the core. This kind of winding has the advantage, in case of localised damage, of facilitating repair work by the removal of the minimum number of sections, and in addition, its own rigidity allows the conductors to resist the mechanical stresses of a short circuit without deformation.

The sections, which are made up with multiple wire

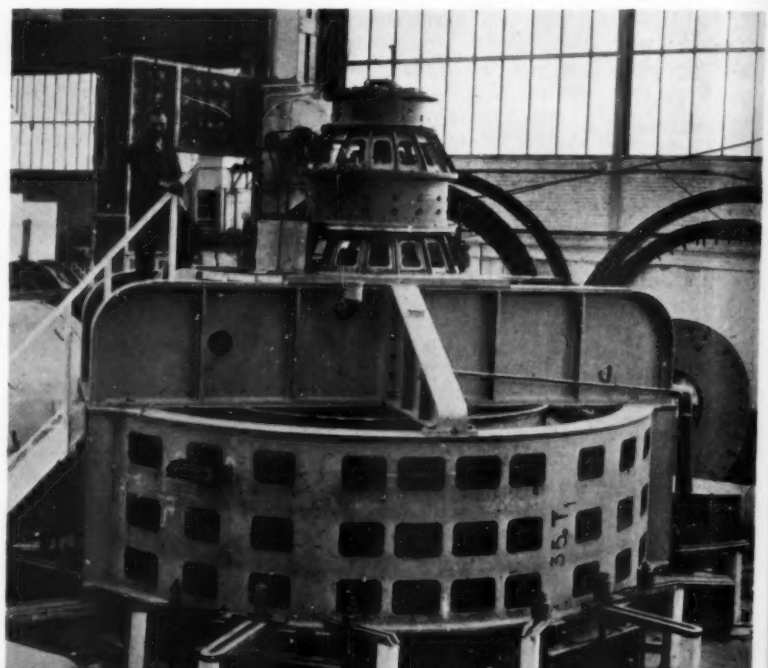


Fig. 1. Standard design of turbine generator with two guide bearings and pivot carried by upper spider

Fig. 2. Frame consisting of two halves welded together

conductors of high conductivity copper are insulated with Class B mica. Mass insulation is effected by a rigid tube in Micartafolium.

The construction of the inductor is shown in Figs. 4, 5 and 6. The flanged, forged-steel shaft receives a cast steel boss on to which thick discs are shrunk. These discs have keys at their periphery for fixing the poles.

The selection of material for the discs depends on certain considerations:—

(a) Continuity of service being essential, a material must be selected which guarantees adequate security in relation to the calculated stresses, keeping in mind that an improvement of the elastic limit of the material is not the only consideration. In effect, the elasticity of the material under the action of unequally distributed loads, is important; for this reason good elongation is desirable if really high security is to be attained.

(b) The determination of the thickness of the disc is a compromise between the safety assured by a large number of thin discs, and the economics of manufacture, for which thick discs are more favourable. Obviously, as the discs have to be machined on large surfaces, economy in material is combined with the economy in machining when the thickness is as great as possible. Fortunately modern metallurgists can produce sheets which offer every security.

In the installation under consideration, the sheets have a thickness of from 50 — 100 mm., their mechanical characteristics being:—

$E = 28$ kgm/mm² $\quad R = 45/55$ kgm/mm²

$A = 25$ — 20 per cent.

Mesuager resilience: 8 kgm/cm²

The discs are fully machined on all faces. Grooves of a depth approaching that of the fixing keys for the poles are milled at their periphery before they are placed on the spider, with the object of avoiding release of tension, which would be produced if they were milled after being placed hot on the rotor spider. The discs are heated and piled on each other on the spider as shown in Fig. 4. The final machining of the slots is then carried out.

The forged steel poles are fixed to the rim by one or more keys locked by tangential pins. The electrodes are made in strip copper folded on the field, each turn being insulated from its neighbour by asbestos. They are pressed hot under a stress greater than the calculated centrifugal force, in order to avoid any possibility of play in service. Fig. 7 shows a complete pole and Fig. 5 the fitting of the poles on the rim.

The upper spider is formed of two longitudinal members of sectional steel which are welded to the central caisson that carries the pivot arrangement and the upper bearing. Deformation of the pivot support must be very slight and therefore great importance is attached to making this part of the upper spider as rigid as possible.

In order to reduce headroom, the upper guide

Fig. 3. Winding shaped to template.

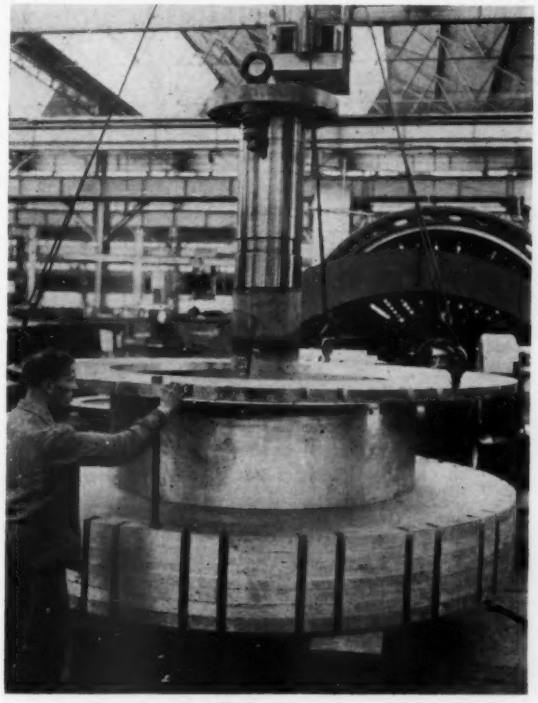
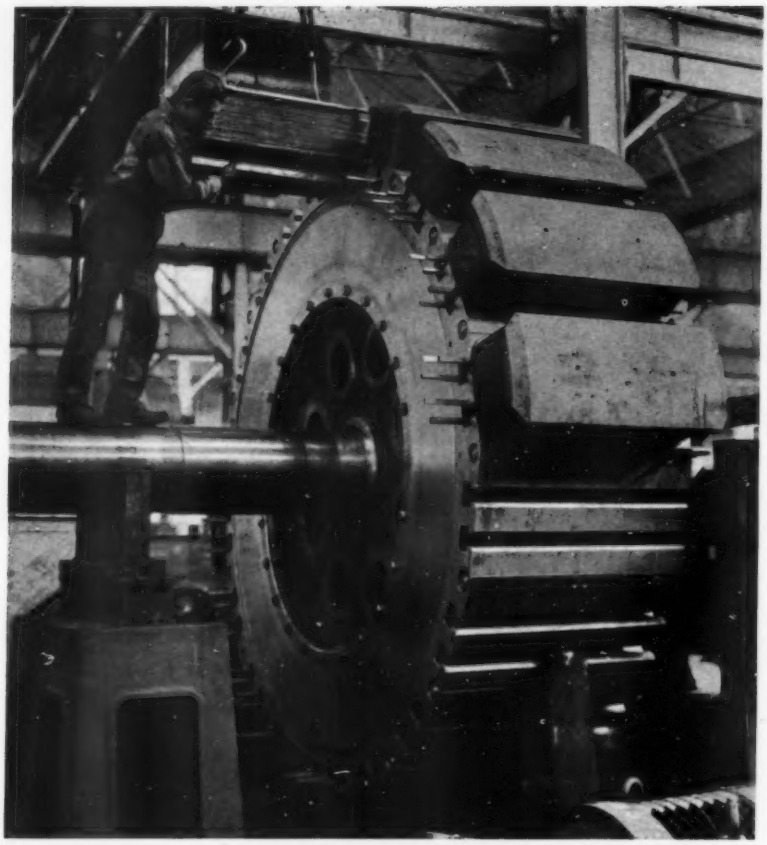


Fig. 4. View of inductor



bearing is combined with the thrust bearing, its lubrication being effected either by the general oil distribution of the group, by a gear pump or a viscosity pump. To avoid circulating losses the pivot and the guide bearing are insulated from the upper spider.

The lower spider comprises a fabricated steel framework the central part of which receives the lower guide bearing, this chassis resting on bases sealed to the foundation. The compressed-air brake cylinders provided with an oil dashpot permit the lifting of the rotor and are fixed to the arms of the spider.

These alternators are generally ventilated on a closed air circuit, the necessary cooling of the air being effected by passing it through coolers.

When low-speed units are required, such as those intended for the power stations on the Meuse, the dimensions become such that a different form of construction is necessary. For an output of the order of 6,000 kVA at 65 revs. per min., for example, the rotor diameter would need

to be 7·50 m. If such a rotor were made in a single piece it would not be transportable and moreover, the construction of an upper bridge would be difficult and expensive in view of the loads to be supported. For this kind of alternator, therefore, the so-called "umbrella" construction is to be preferred, the pivot being supported either by the lower spider with a reduced seating, or by the casing of the turbine. In either case the upper bridge is abolished and replaced by a light girder serving as a support for the exciter inductors and the pilot alternator. A thin steel plate covers the top of this beam. By making an umbrella construction a considerable reduction in weight and headroom is secured, and the height of the turbine hall can be reduced—a not inconsiderable consequence.

Fig. 5 (top). Fitting pole pieces on to rim

Fig. 6 (above). Another view showing fitting of pole pieces

Fig. 7 (above, right). A complete pole piece

When the thrust bearing is supported by the lower spider, the guide bearing is combined with the thrust bearing and this has the advantage of necessitating a single lubricator only, with consequent reduction of space requirements. When the pivot is supported by the turbine casing, the guide bearing is brought above the rotor and fixed on the girder supporting the exciters. The rotor is, of course, assembled in the power station.

The inductor spider, which consists of a cast steel boss to which the arms are attached, ensures the centering of the rim which is effected by the assembly of thin lap jointed segments held by bolts. When the assembly of the rim is completed, it is heated and centred in relation to the spider by means of shims introduced between the internal periphery of the rim and the ends of the arms. The thickness of these shims is selected to give sufficient freedom to prevent any tendency to bend at normal speeds. Balancing of the rotor is effected by means of a ball centre.

Improved Folding Weigher

Among the many advantages claimed for a new Blaw Knox folding weigher are a substantial reduction in weight and a more efficient cradle design. Weight reduction has been effected chiefly by the use of aluminium alloy, which also has the advantage of making a more rigid structure and this, in turn, leads to the improved stability of the unit when it is moved in the "folded" position. The weigher can be supplied for either the firm's 10S or 7S Rex type concrete mixers, and can be fitted in the field; the net weight of the weigher (less the mixer) is 3½ cwt. for the 10/7S unit and 4¼ cwt. for the 14/10S.

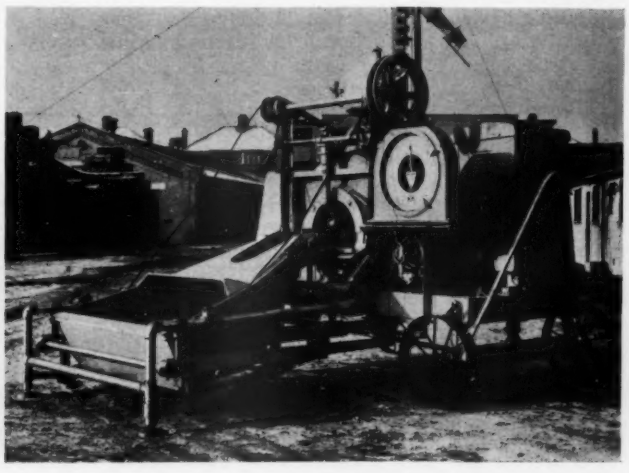
Another improvement lies in the pivoting of the weigh-beams, in which sealed roller bearings have been substituted for "knife edges." A three-point suspension has also been introduced to prevent "racking" of the weigher and the necessity to level up the mixer. Built-in stabilising jacks give easy adjustment, and bonded rubber joints effectively insulate the weighing dial from the mixer frame and thus prevent damaging vibrations from being transmitted to the weighing mechanism. During weighing the skip is entirely free from contact with the mixer.

Our illustrations show the unit variously in the folded position and in the operating position, and give evidence of the compactness of the design.

N.C.K. Excavators

THE N.C.K. 304 excavator manufactured by Newton Chambers & Co. Ltd. is essentially a universal machine and can be adapted as a face shovel, a drag shovel, a drag line, a grab crane and a lifting crane. As a face shovel it has a bucket capacity of ¾ cu. yard and has a wide range of speeds to meet different operating conditions. The conversion to a drag shovel is simply and quickly effected and as such it has a long, deep, digging reach. The conversion to a dragline operation requires the provision of a lattice jib which can also be used when the machine is used as a grab crane or lifting crane.

It is claimed that the engine and machinery are



accessible in spite of the extremely compact design and that the wide range of operating speeds, which can be applied with convenience, enable the N.C.K.

304 to tackle a great assortment of tasks with maximum speed and economy.

Power is provided by a 66 h.p. six-cylinder diesel unit and is transmitted to the gearing through a single-plate clutch of the gear-tooth type, and which is fully adjustable to take up wear. A petrol engine or electric motor can be substituted for diesel power unit if required. Transmission between the engine and swing and traction shaft is by means of a multi-strand roller chain which runs in an oil bath.

The crawler assembly is designed to be free from clogging and the liberal use of guide rollers ensures an even distribution of the weight along the entire length of the guide frame. Adjustable bearings at each end of the frame afford a quick and easy means of tensioning the tracks. A safety device enables the brakes to be applied on the horizontal propelling shaft at any time, without disengaging the multi-tooth clutches. The main gear case is completely sealed and runs in an oil bath, and all the high-speed shafts are equipped with ball or roller bearings.

A full-vision cab enables all operations to be kept within complete view and this, combined with the ample power available and flexibility for quick manoeuvring, and ease of control, constitutes a further feature conducive to high rates of output.

Tube Bending Machine

Chamberlain Industries Ltd. have recently redesigned their 2 in. bending machine as a compact and entirely self-contained unit. No hydraulic accumulator or airline is required as the pump is mounted in its own reservoir. The overall dimensions are 3 ft. 1 in. by 2 ft. 1½ in. by 1 ft. 7 in. and this compactness gives the operator the distinct advantage of being able to walk round the machine without tripping over extraneous fittings such as outside cylinder or hose, and he has an uninterrupted view of the work at the "bending head."

The power unit is totally enclosed by a detachable top housing, and hydraulic power is provided by a Beacham high-pressure swash-plate pump mounted directly above an 8 ton × 10 in. stroke double-action ram unit. The pump unit is driven by a ½ h.p. electric motor suitable for 220-230 V single phase, 50 cycles supply, or, alternatively, a 400-440 V three-phase motor. A panel is incorporated in the rear of the housing cover from which extends a 7 ft. length of V.I.R. cable for connection to a three-pin plug. A three-way control valve fitted with a relief valve for "forward," "return" and "neutral" position is operated by an easily accessible lever mounted at the front of the machine. All the connecting pipes are made from two-wire braid high-pressure flexible hose with oil-tight connections.

A novel feature has been introduced to facilitate easier removal of the bent tube from the bending formers, this taking the form of off arms which are provided on the end formers so that on the return stroke the tube is automatically ejected from the former. A further time-saving feature is provided by castors which give the machine complete mobility, enabling it to be taken to the work instead of the work being brought to the machine.

It has ample power to bend, cold and unloaded, all classes of steel tubes to B.S.S. 1387:1947 and also

electrical conduit tubing from ⅜ in. to 2 in. It operates under fingertip control, and does its work with precision without any fatiguing physical effort on the part of the operator.

"Festival Electric"

The North of Scotland Hydro-Electric Board is holding in Dundee from April 10—14, an exhibition which will be the biggest of its kind ever staged in Scotland and will entirely fill the Caird and Marryat Halls and all their subsidiary rooms.

Among the board's exhibits will be a 60 ft. working model of the Pitlochry Hydro-Electric Scheme. This is understood to be the biggest working model ever shown at an exhibition in this country. A similar but smaller exhibition held by the board in Aberdeen last year was attended by more than 80,000 people.

Large Transformers for India

FIRST two of a number of 20 MVA three phase 100/6.6 kV Hackbridge transformers were recently shipped to India, destined for installation at the Parel receiving station of the Tata Hydro-Electric Power Supply Co. Ltd., in Bombay. These units are to replace existing single phase banks at Parel, which have been in service since 1916. They will operate at the receiving end of a nominal 115 kV transmission system and are provided with H.V. tappings of ± 2½ and 5 per cent., + 7½ per cent. and + 10 per cent., selected by off-circuit switch, to permit voltage adjustment. As the existing transmission system is on a lower voltage, however, the transformers are provided with a full capacity H.V. tapping for 85.8 kV on which they can be operated in parallel with the existing transformer banks, pending changeover to the higher voltage system.

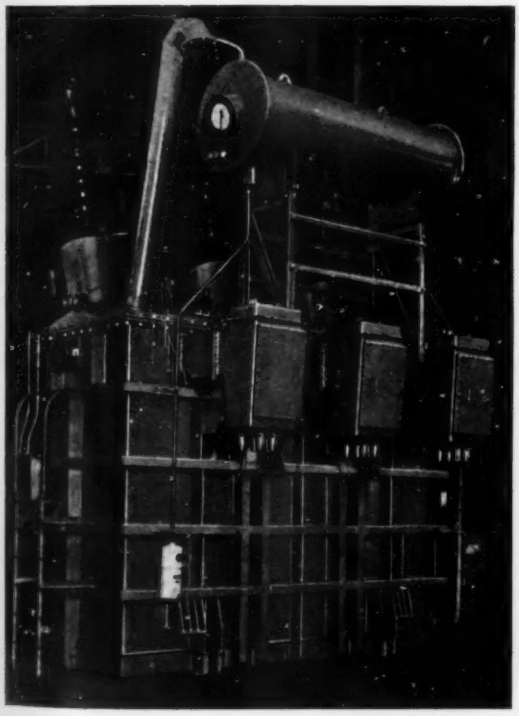
They are outdoor units and will be subjected to relatively severe operating conditions, since at Parel, ambient temperatures are reached of up to 45°C. in the sun, while during the monsoon period the substation is subjected to high winds from the sea and to torrential rainfall of up to 20 in. in 24 hours. The transmission system also is in an area subject to lightning storms. To meet these conditions the transformers are designed for a temperature rise of 40°C. (oil) and 55°C. (by resistance) and to have an impulse voltage level based on 550 kV and 95 kV respectively for the H.V. and L.V. windings, with a 1½/40 microseconds full wave.

Connected star/star, the units are equipped with a 33⅓ per cent. delta tertiary winding. The ends of this winding are brought out for testing purposes to terminals, which are normally protected by polythene insulating covers. The H.V. and both the neutral terminals are porcelain bushings while the L.V. windings are brought out to disconnecting chambers and cable boxes, equipped to receive 5 single-core cables per phase.

Cooling is by means of a Serck, horizontal, water cooled heat exchanger compactly mounted on one end of the transformer, the oil being circulated through a bank of tubes cooled by water.

In accordance with the latest Hackbridge practice, covered by patent application, the oil feed from the conservator vessel is piped to the bottom of the transformer tank, with a corresponding departure from the orthodox layout of the oil expansion and air release pipework, an arrangement which, with its effect of maintaining the oil in the conservator vessel at a lower temperature, reduces oil deterioration in service and is obviously of particular value on units for service under tropical conditions.

The accompanying illustration shows one of these transformers in the works of the makers, Hackbridge and Hewittic Electric Co. Ltd. Shipment was effected without oil, the transformers being sealed in dry air under pressure, to reduce weight in transit to site, where they will be filled with oil. Weight of each unit complete with oil is 55 tons.



Elan Valley Installation

Gilbert Gilkes & Gordon Ltd., Kendal, have received the order for two 215 kVA hydro-electric units for installation at the Elan Valley Waterworks of the City of Birmingham Water Department. These will replace the 60 kW "Gilkes" turbines which are now more than 45 years old, and will utilise to the fullest practical extent the potential power of the compensation water which has to be discharged continuously into the River Elan from the lowest of the Corporation storage reservoirs. Some of the power will be utilised locally for the requirements of the plant and property owned by the Water Department and the surplus will be fed to the nearest mains of the South Wales Electricity Board's supply area.

The turbines will be of the spiral-cased Francis type, suitable for operating under a head which may, under extreme conditions, vary from 103 to 45 ft. The opening of the turbine guide vanes will be set by hand. When operating in parallel with the grid, the alternators will deliver a steady output, the speed being controlled by the grid frequency.

The units can, if necessary, be isolated and will continue to feed the local area. In these conditions the speed will be controlled by the recently patented "Giljet" governing system. This consists of a hydraulic brake in which the braking effect is obtained by allowing a jet of water to impinge upon a series of buckets formed in the rim of the flywheel, the buckets moving *towards* the jet and not *away* from it as is the case with a normal Pelton wheel. The volume of water impinging upon the brake disc is controlled by means of a standard oil pressure governor. With this system, it is claimed that very close speed regulation can be obtained with a small variation in the flow of water through the turbine under all load conditions. The alternators and associated switchgear are to be manufactured by the Metropolitan-Vickers Electrical Co. Ltd., of Manchester.

New Self-Regulating Alternator

THE "Magnicon" alternator is claimed to have several advantages over conventional types because its characteristics provide for an inherent voltage regulation of plus or minus 2½ per cent. and for accidental 3-phase short-circuits without harm. As the result, the machine can be operated without an automatic voltage regulator so that there is a direct saving in the cost of the installation and maintenance. For applications where a closer voltage regulation is required it can be designed with an inherent regulation within plus or minus 1 per cent.

Within the limits laid down in the British Standard for internal combustion engines, varying speeds make no difference to the regulating action, and the control circuit is not affected by any change in frequency; and for hydro-electric applications the same advantages are obtained so long as the runaway speed of the turbine is curbed sufficiently to prevent mechanical troubles from developing.

The magnetic design allows for a "Magnicon" machine to have a wide voltage range. For example, a 400 volt alternator will still give its full kVA output at 440 volts, and at voltages below 400. In practice with a slight increase in frame size for a given capacity, full kVA output can be obtained over a range of about 380 to 440 volts.

By appropriate design, the "Magnicon" alternator can also give its full output on widely differing voltages, e.g. 208 volts, 3-phase, 60 cycles, and 416 volts, 3-phase, 50 cycles. The change from one voltage to the other is made by switching in or out a ballast resistance in the control circuit by means of a 5 amp. switch.

Rotating field machines can be designed to give either one of two different voltage ranges by changing external stator winding connections. Two forms of winding are available: (1) star or delta connection for rated voltages in the ratio 1.73 : 1, e.g. 346 and 200 volts; (2) series or parallel connection for rated voltages in the ratio 2 : 1, e.g. 400 and 200 volts. At any rated voltage the standard voltage variation is obtainable.

It is an obvious advantage to have these machines available where it is required to meet urgent demands from stock, particularly for oversea applications. To obtain the operating voltage required within the range of the machine, a hand-operated rheostat is fitted. Once this has been adjusted the machine is self-regulating within the limits determined by its design. The voltage regulation of standard machines is unaffected by out-of-balance currents up to 25 per cent. of full load. With specially designed machines a larger percentage of out-of-balance current can be carried without affecting the voltage regulation.

Operation and Construction

The "Magnicon" alternator is unaffected by a 3-phase short-circuit because the resultant voltage-drop will de-magnetise the exciter field so that after a momentary rise of current this rapidly decreases and the alternator can run short-circuited indefinitely without any damage to the winding. Nor does the machine require to be synchronised in the same way as a conventional type of alternator. It will pull into step easily with a minimum of disturbance when there is a difference in voltage or phase. This characteristic makes it particularly suitable for operation by unskilled attendants. The alternators can be operated in parallel, and by using "paralleling links" to connect the compensating windings, they will share the watt-less load more closely and easily than conventional alternators. Although of light cross-section (a 3/.029 cable is sufficient) the links serve the same purpose as the equaliser on compound D.C. generators. The proportion of watt-less load required can be set at any particular value and the machines will then continue to supply these proportions at all loads.

Another feature of the design which recommends it for application where the attendants are comparatively unskilled is that it will not be affected by the accidental opening of the control circuit, for if this occurs the generated voltage will fall to zero immediately. With the ordinary type of automatic voltage regulator an open circuit may result in a dangerous increase of voltage.

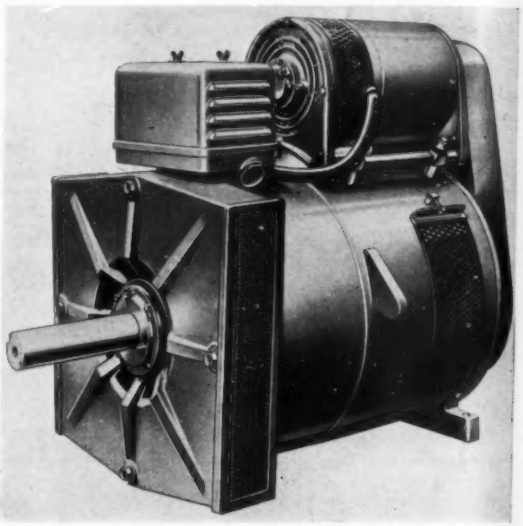


Fig. 1. Typical Magnicon self-regulating alternator showing special exciter mounted on top of the main machine

The design enables the alternator to be constructed as a revolving-field machine at an economical price in smaller sizes than before. At the same time it is usually smaller in external dimensions than conventional types.

The construction is, in fact, similar to an induction motor, the D.C. poles being "non-salient," i.e. the length of the air gap is uniform all round. This enables the field winding to be distributed and the iron in the field magnet to be fully laminated.

The advantages claimed for this form of construction are:—

(a) The laminated core and the small distributed coils permit speedy response to changes in exciting current.

(b) Because the pole pieces do not project, other things being equal, it is apparent that the alternator must have a smaller outside diameter than the conventional salient-pole machine.

(c) The rotating-field type of machine can be made at an economical price in smaller sizes than is possible with a salient-pole design.

The field winding, in addition to its function as an exciting winding, is connected to act as an A.C. multi-phase short-circuited field. In consequence, the following characteristics are obtained:—

(a) The winding acts inherently as a "damper" and reduces or eliminates pulsation in single-phase machines.

(b) By choosing a suitable winding pitch, the shape of the D.C. field can be made sinusoidal and harmonics in the voltage wave eliminated.

(c) All alternators have a sinusoidal armature reaction and a sinusoidal field is needed for compensation. This type of field is provided by the distribution of the field winding itself and therefore shaped pole pieces with large air gaps are not needed.

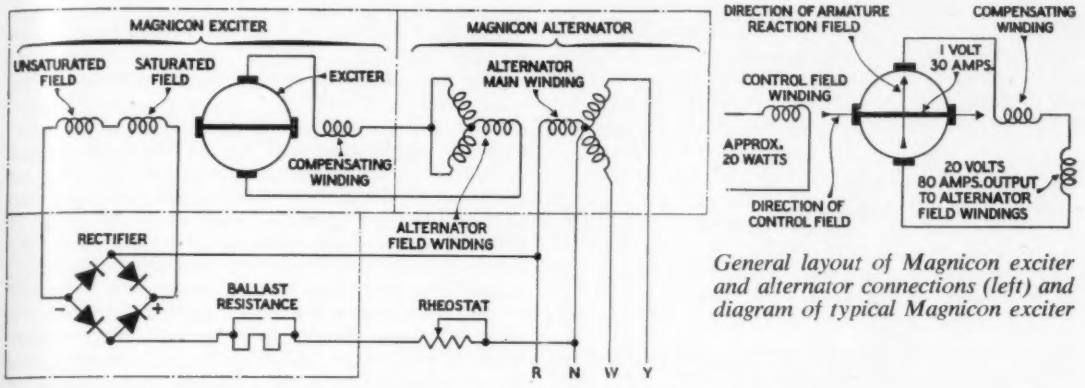
(d) Paralleling is made simple as exact synchronising is unnecessary. The special field winding enables the machines to pull into step with the minimum of disturbance.

Principles of Operation

To derive the advantages resulting from this special design and construction, the exciter has been developed to have an equally rapid response to control. To ensure a high alternator performance the exciter must be adequate to meet the excitation required at all loads and prime-mover speeds, and it must also be capable of changing its output instantaneously in order to maintain constant supply voltage under varying load conditions. An exciter of conventional design can be made to provide adequate excitation but it cannot vary the excitation unless controlled by an automatic voltage regulator. It is the combination of "Magnicon" alternator with "Magnicon" exciter which allows for close voltage regulation without an automatic voltage regulator.

The exciter is of the "cross-field" type and has the characteristic of magnifying a small input from a control source into a large output almost instantaneously. It is outwardly similar to a conventional exciter and has a fully laminated field system with a distributed field winding which gives it the same rapid response as the "Magnicon" alternator. The brushes are connected differently from a conventional exciter but otherwise there is no more complication.

The exciter functions in accordance with the simplest principles of dynamo-electric machines. A field winding is supplied with D.C. from a small metal rectifier connected to the output terminals of the alternator. This field is responsible for the generation of a current in the armature, but the circuit in which it flows is closed by a short-circuited connection across the brushes. The current sets up an armature reaction which produces another magnetic field at right angles in space to the original control field. The field produced by armature reaction is responsible for the generation of another current which is collected by a second pair of brushes, at right angles to the other set, and fed directly into the alternator field.



General layout of Magnicon exciter and alternator connections (left) and diagram of typical Magnicon exciter

It should be noted that although the output current also produces armature reaction this is cancelled by the compensating winding so that it will not interfere with the original control scheme. The compensating winding is carried in additional slots on the pole faces of the exciter and it can be arranged to over-, level-, or under-compound the alternator.

Because the controlling power required is very small it is convenient to make the actual field of the "Magnicon" exciter equal to the difference of two strong fields acting in opposition on the same poles. These fields "balance" when the alternator voltage is correct. One field is practically constant, being magnetically saturated, while the other is unsaturated so that it varies in strength with the alternator voltage. If the alternator voltage falls, the difference in field strength resulting is magnified by the action of the "Magnicon" exciter to produce sufficient output to boost the alternator voltage until the original state of balance is restored.

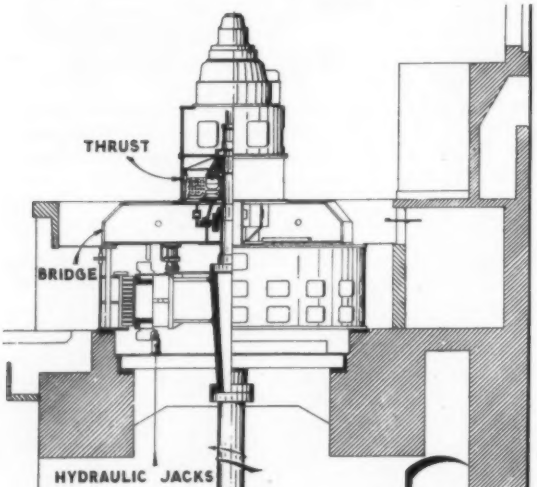
The complete "Magnicon" unit is shown in the accompanying photograph. The exciter is usually mounted on top of the alternator and driven at about 3,200 r.p.m. by vee belts. A simple device for adjusting the belt tension is provided. The overall length of the set is reduced by having the exciter mounted on top of the alternator and not directly coupled, but the latter arrangement is available when it is required to pass ventilating air through a filter before it enters alternator and exciter.

"Magnicon" alternators are being manufactured by Messrs. Crompton Parkinson Limited, who have received an exclusive licence from The Macfarlane Engineering Co. Ltd., Glasgow. At present they are available in the following range of sizes: 5 kVA—150 kVA at 1,500 r.p.m., 4 kVA—130 kVA at 1,000 r.p.m., 3 kVA—100 kVA at 750 r.p.m., and at 1, 2 and 3 phase, 25 to 60 cycles, 100—600 volts.

From the Journals of the technical institutions and other material published in the Press of the World

Measuring hydraulic thrust in vertical-shaft Francis turbines

A delicate problem, when designing vertical Francis turbine units, is to determine the dimensions and characteristics of the thrust bearings which, in addition to carrying the weight of the rotating parts, have also to cope with the hydraulic thrust on the blades of the runner; on the one hand, it is impossible to



calculate this thrust accurately, while on the other, unstable conditions may develop because of cavitation at the runner outlet, vibrations and so on.

In the method described in this article the bridge or girder carrying the thrust bearing is used as a dynamometer, being graduated for this purpose according to the distortion brought about by a determined load, such, for example, as the weight of the rotating parts. As this distortion is linear, it is easy to measure the thrust and its fluctuation as the load of the turbine varies. The only difficulty lies in the smallness of these distortions which are thus not easy to measure. The authors claim to have obtained good results with a Father Cayère water-level having the following characteristics:—

Radius of bubble ..... about 174 ft.
Number of graduations of bubble 120
Magnifying power of microscope ... about 30

A level difference of 1 micron between two points 3 ft. 3 in. apart caused the bubble to move to the extent of 1.59 graduation so that slopes of less than 0.5×10^{-6} radian could be measured. The degree of accuracy of this water-level is therefore amply sufficient but could be doubled by using a bubble with a radius of 328 ft.

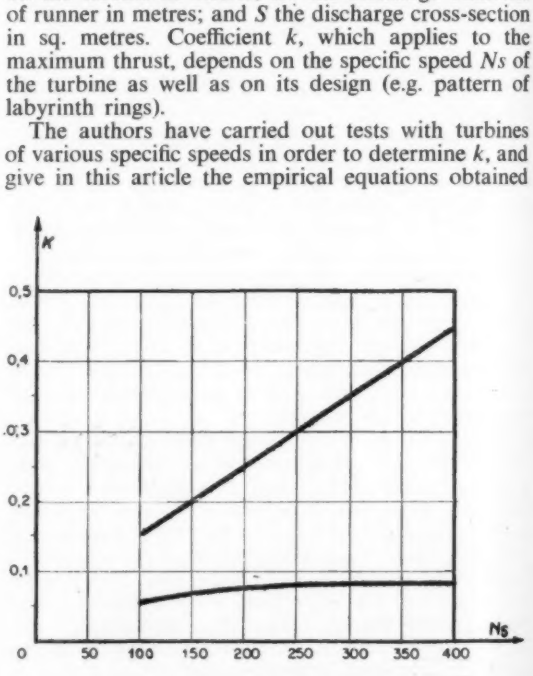
The measurements are obtained by fixing on the water-level to the bridge or girder at a suitable spot, so that the movements of the bubble can be easily observed. In the appended diagram the thrust bearing is carried by the bridge which, in its turn, rests on the stator of the generator. Hydraulic jacks are used to raise the rotating parts so as to free the bridge or girder from any load. After the water-level has been fitted on at a suitable spot, the position of the bubble is set. The whole unit is then lowered so as to rest on the bridge, and the movement of the bubble is recorded. Once this gauging has been effected there is no difficulty in ascertaining the load corresponding to one graduation of the level. Measuring the hydraulic thrust and its fluctuations in relation to the load of the turbine is easy if the unit is submitted only to negligible vibration.

The hydraulic thrust is generally calculated by means of the following semi-empirical equation:—

$$P = k \times \frac{Ds^2}{4} \times H = kSH$$

in which P is the hydraulic thrust in tons; H the head on the turbine in metres; Ds the discharge diameter of runner in metres; and S the discharge cross-section in sq. metres. Coefficient k, which applies to the maximum thrust, depends on the specific speed Ns of the turbine as well as on its design (e.g. pattern of labyrinth rings).

The authors have carried out tests with turbines of various specific speeds in order to determine k, and give in this article the empirical equations obtained



with three vertical-shaft Francis turbines:—

(1) Ns 100.

N = 42,500 h.p., n = 500 r.p.m., H = 255 m. (under test 253 m.), Ds = 1,275 mm.

P at maximum load = 0.153 SH = 49.5 t.
P at no load = 0.056 SH = 18 t.
Ratio of P maximum to weight of rotating parts: 0.4.

(2) Ns 200.

N = 56,000 h.p., n = 214 r.p.m., H = 89 m. (under test 86.5 m.), Ds = 2,750 mm.

P at maximum load = 0.253 SH = 130 t.
P at no load = 0.078 SH = 40 t.
Ratio of P maximum to weight of rotating parts: 0.565.

(3) Ns 400.

N = 2,660 h.p., n = 250 r.p.m., H = 16.5 m., Ds = 1,700 mm.

P at maximum load = 0.46 SH = 17.5 t.
P at no load = 0.080 SH = 3 t.
The thrust at maximum load in this turbine is about equal to the weight of the rotating parts.

The same tests have been carried out on the Ns 400 Francis turbine by the French Electricity Authority (Water Power Branch, General Engineering Section), the distortion of the bridge in this instance being measured by means of an extensometer fitted with a strong wire. The results obtained were more or less the same as those given above.

The graph (page 118) gives the value of thrust coefficient k in the equation $P = kSH$ for maximum load as well as for no load.—*S. X. Casacci and P. Jarriand, La Houille Blanche*, Vol. 5, No. 3, p. 326, 7 pp., 9 ff.

Economical layout of tunnel systems

The problem dealt with in this article is set out as follows by the author, M. J. Conte, an engineer attached to the Alpes I Development Region of the French Electricity Authority: "A certain number of fixed points have to be connected by a given system of tunnels of a given cross-section. Determine the geometrical layout involving the lowest possible expenditure."

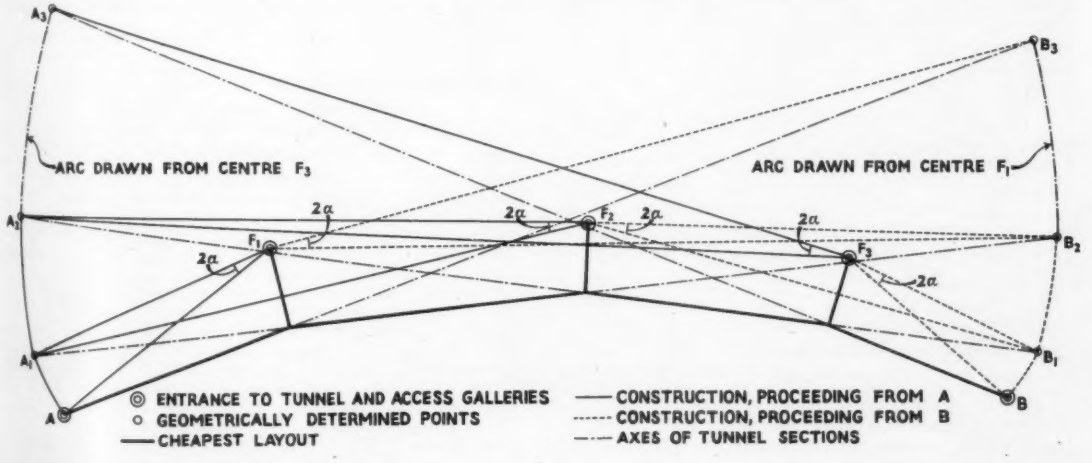
The author proceeds from the assumption that the ground in which tunnelling is to be carried out consists of either one or of several zones, that the limits of each are either known or assumed, and that the cost of tunnelling per length unit in each zone is known. Tunnels proper, tunnel junctions, and systems comprising access galleries are discussed separately. The following rule is laid down as a basis for working out the most economical layout of a system of tunnels: "In non-homogeneous ground, consisting of separate homogeneous zones, the most economical layout of a tunnel is a broken line which is subjected at every boundary of two neighbouring homogeneous zones to a refraction of which the coefficient is equal to the inverse of the ratio of the cost per length unit in the two corresponding zones of the tunnel to be driven."

The author warns, however, that this rule or any conclusion drawn from it should not be taken as axiomatic since his considerations are of a purely mathematical order; it should rather be accepted as a guide which, once engineering requirements have been taken into account, will enable the designer to work out the theoretical layout involving the smallest expenditure. The diagram shows the application of this method to a tunnel comprising, in addition to inlet A, three "windows" or access galleries F, and an outlet B. — *J. Conte, La Houille Blanche*, Vol. 5, No. 3, p. 333, 9 pp., 16 ff.

Trends in transformer application

The economical application of transformers is a very important part of an electrical system. Considerable improvements have been made in the last 20 or 30 years and, with modern designs and materials, as well as a better understanding of insulation fundamentals, engineers have developed units which practically rule out failures from lightning and switching surges. This article, written by a transformer specialist, gives a short but comprehensive survey of the main features to be considered in up-to-date transformer design, *viz.* cooling, insulation, functional needs, and cost.

Cooling practice differs. Through the addition of fans or blowers the old so-called self-cooled transformer has become the forced-air cooled type; by circulating oil through radiators with pumps, whilst



air is being blown over the radiator, we have the forced-oil cooled transformer.

Insulation level varies with application. The contention that the basic insulation level of higher voltage transformers can be safely reduced one class below standard, if proper protection is provided, has been substantiated by practice.

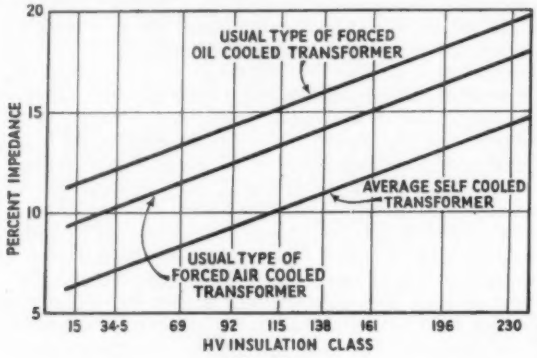


Fig. 1

A comparison of weights and dimensions for the various ways of handling a 75,000 kVA, 138 kV to 13·8 kV, three-phase load is shown:—

	Self-cooled	Self-cooled Forced Air	Forced Oil
Total weight .	100%	90%	70%
Floor area . .	100%	90%	70%
Overall height	100%	95%	90%

Against the advantage of being completely self-contained the self-cooled transformer is heaviest in weight, largest in dimensions, and costs most. Forced-oil cooling has clear advantages over other methods when floor space is a limiting factor.

Transformer insulation level and method of cooling have a material effect on transformer impedance, as shown in Fig. 1, in which the normal impedance of a transformer is seen to increase with the insulation level and with the forced methods of cooling.

Regulation is determined by the difference between actual full-load and no-load secondary voltage of a transformer with the impressed voltage held constant. The voltage difference increases as the load is increased from zero at no load to an appreciable value at full load. Fig. 2 compares average regulation at 0·8 power factor in transformers cooled by various methods, and indicates that forced-oil cooled units need the most regulation.

A system load can be handled among other methods by either three single-phase or one three-phase self-cooled transformer; combined copper losses are the same in both instances but the core loss will be about 20 per cent. higher for the single-phase units because of the less efficient use of core steel.

The initial cost of a transformer bank can be materially reduced by utilising three-phase instead of single-phase construction; a further reduction can be obtained by taking advantage of the various types of cooling equipment, and by reducing the insulation level of the high-voltage winding. When selecting a transformer, it may be desirable to temper initial cost by loss evaluation which places a monetary value on each kilowatt of loss; the simplest method is to use commonly accepted values per kilowatt of no-load

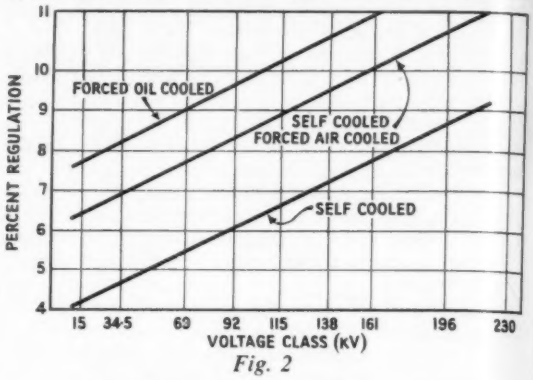


Fig. 2

loss, and per kilowatt of load loss. In Fig. 3 the losses have been evaluated by another simple method which consists in using a rate from three to seven mils (mil = one thousandth part of one dollar) per kWh for the life of the transformer; the rate applied to this graph is three mils per kWh, and the curves permit a comparison to be made with self-cooled and forced-air cooled transformers at various load factors. It is obvious that the initial cost advantage of the forced-air cooled transformer is offset by the three mil loss

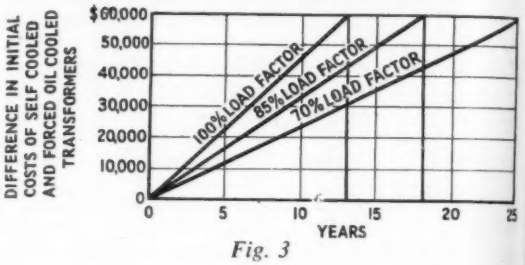


Fig. 3

evaluation in 13 years for the 100 per cent. load factor.

Both methods of evaluating consider only the cost of generating the losses—generally neglected in hydro systems—and do not take the loss of revenue energy into account. Loss evaluation is complex and will differ for each system and, for that matter, for each part of a system.—L. W. Schoenig, *Allis-Chalmers Electrical Review*, 1950, p. 20, 4½ pp., 11 ff.

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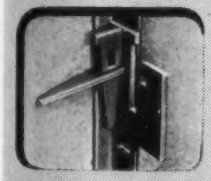

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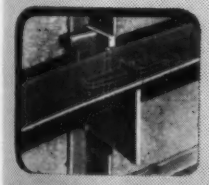

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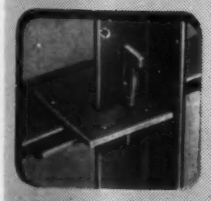

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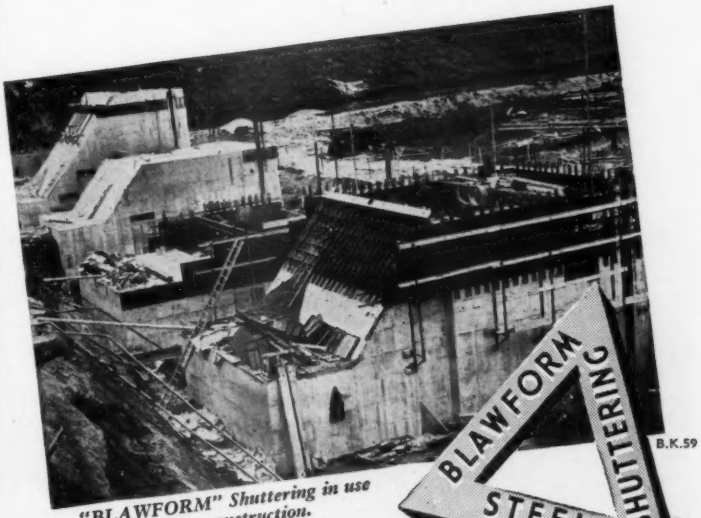

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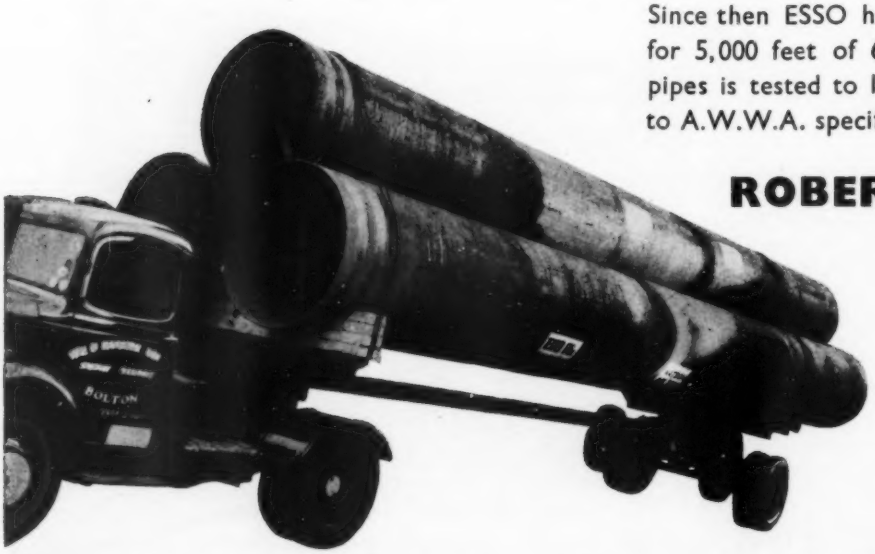

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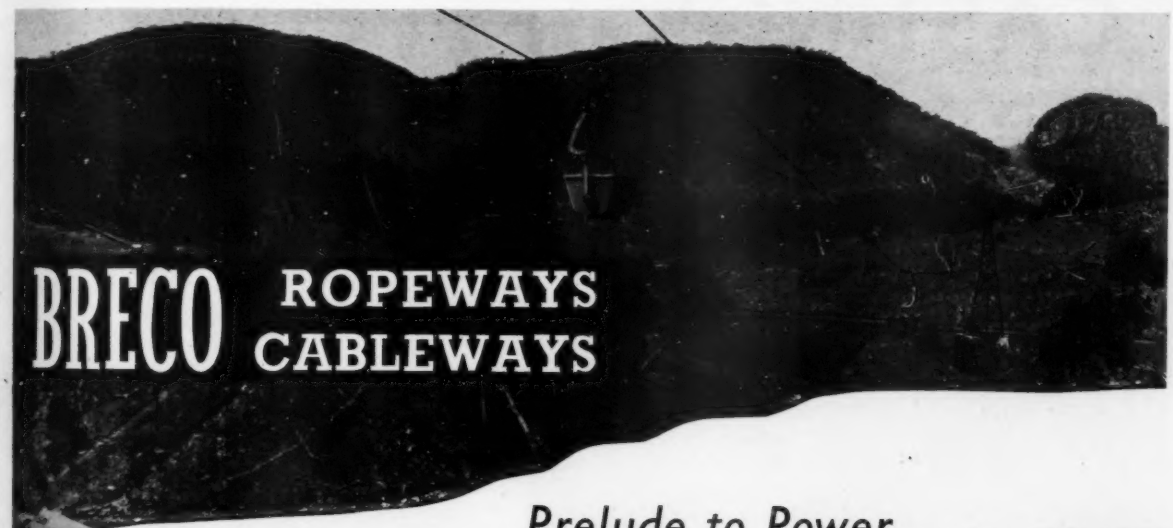

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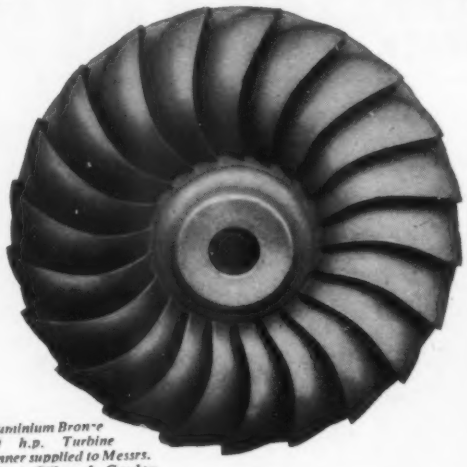

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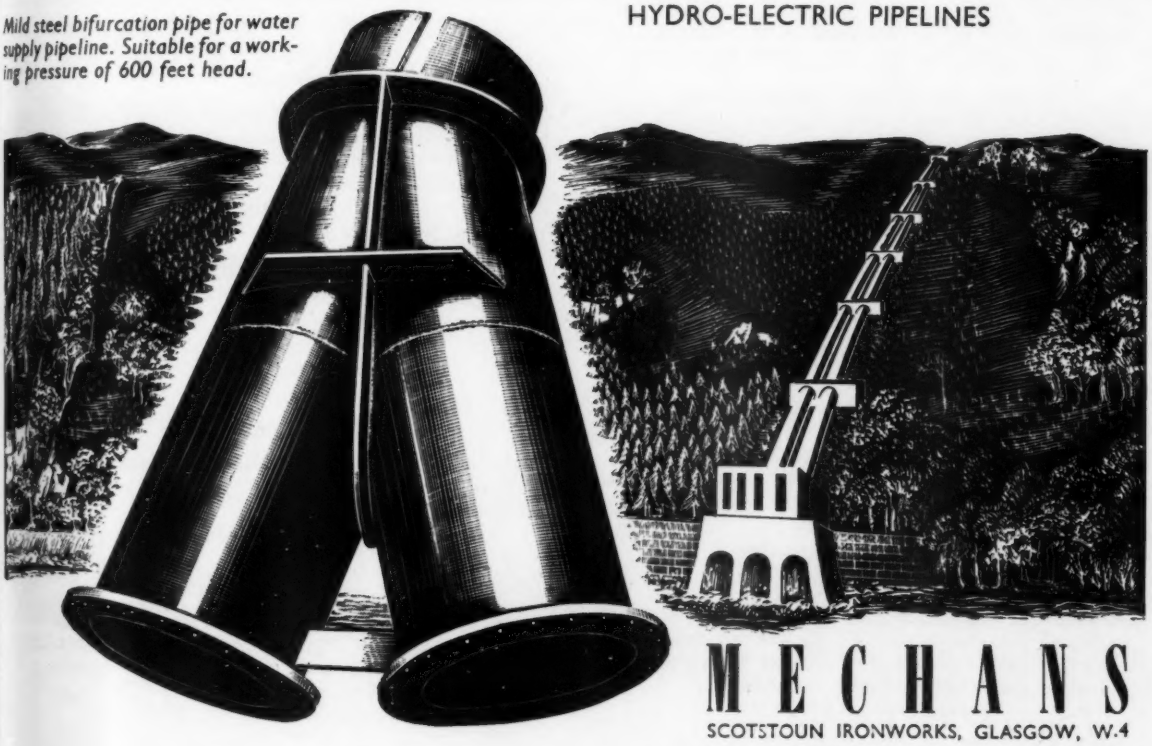

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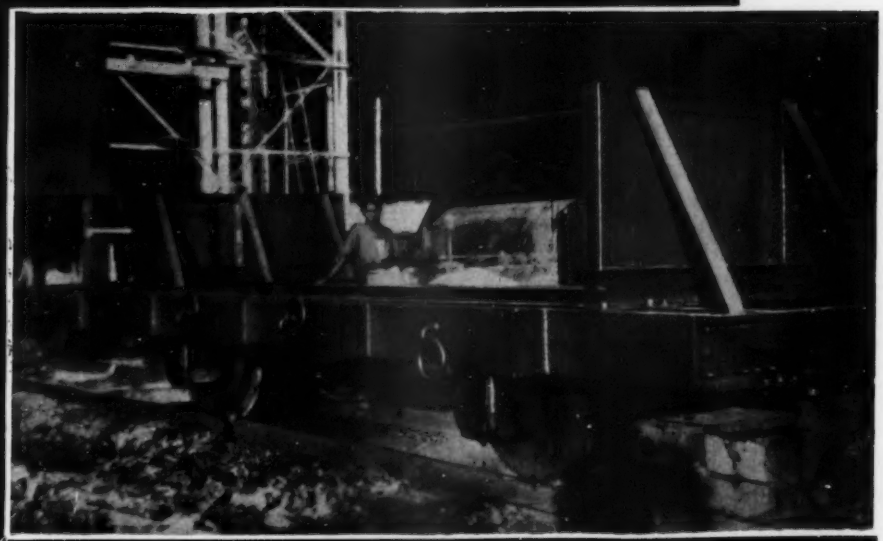

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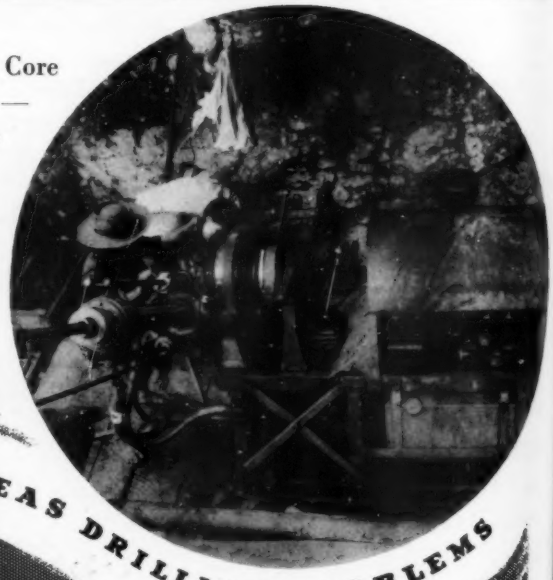

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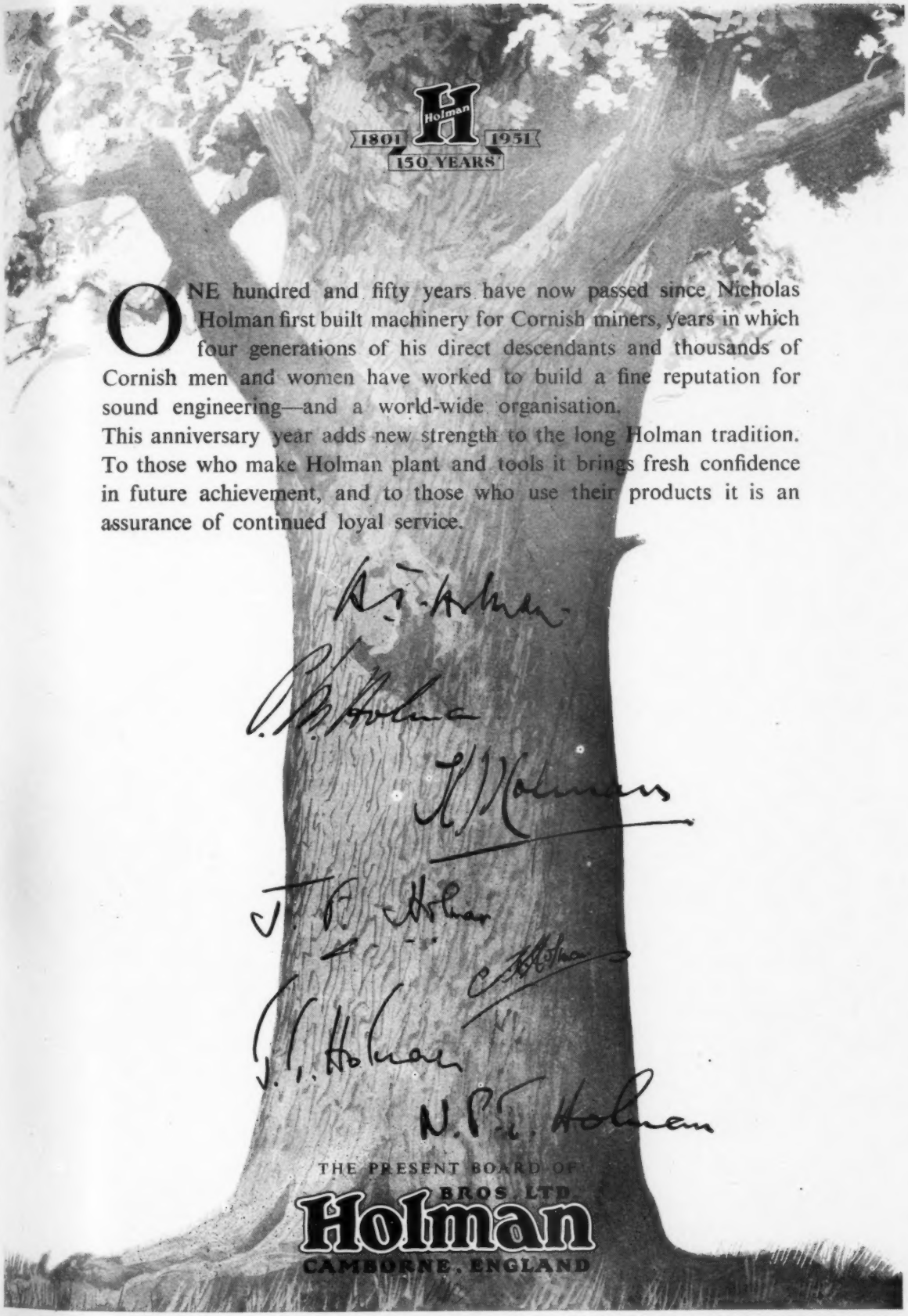
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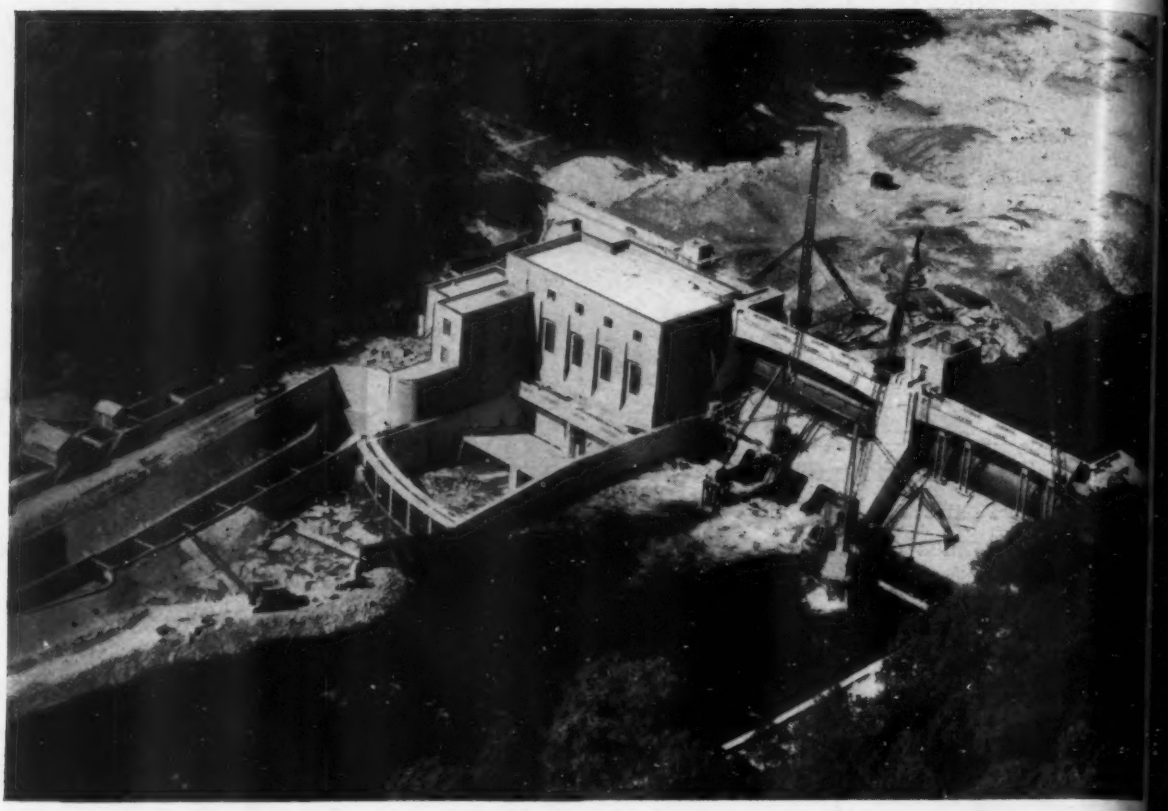

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